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WM. SPRARAGEN
Editor

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SOCIETY AND RELATED ACTIVITIES

Annual Meeting

The fourteenth Annual Meeting of the AMERICAN WELDING SOCIETY was held at the Governor Clinton Hotel on April 27th and 28th.

The meeting was devoted very largely to business sessions, committee meetings and several lectures. There was a registered attendance of 135.

The reports of the Pressure Piping Code Committee and the Committee on Use of Welded Steel Parts for Machinery Construction were well received and both will be available very shortly for publication. An outstanding feature of the business session was the reports of activities of the various sections and the presentation of the Samuel Wylie Miller Memorial Medal. Three unusual addresses were presented as follows:

"Erecting Steel Buildings and Strengthening Steel Bridges by Welding," by Professor F. P. McKibben.

"Must Industry Be a Pawn or a Power?" by Charles F. Abbott, Executive Director, American Institute of Steel Construction.

"Welding—a Factor in Industrial Revival," by Willard T. Chevalier, Publishing Director, *Engineering News-Record*.

The American Bureau of Welding held its Annual Meeting on Friday afternoon. Special progress reports were presented by the Welded Rail Joints Committee, Structural Steel Welding Committee and Welding Wire Specifications Committee. Interesting reports of progress were made by the Chairman of the Fundamental Research Committee, the local subcommittee Chairman and individual university and governmental investigators.

Election of Officers

The following officers of the AMERICAN WELDING SOCIETY were elected to serve for one year:

President—Frank P. McKibben
Senior Vice-President—John J. Crowe

The following Directors were elected to serve for three-year period:

W. H. Gibb, H. S. Smith, J. C. Lincoln, W. C. Swift and Andrew Vogel

The following divisional Vice-Presidents were elected to serve for two-year period:

Pacific Coast Division—D. J. Williams
Southern Division—G. Raymond

At the Board meeting C. A. McCune was reappointed Treasurer and Miss M. M. Kelly was reappointed as Secretary and Assistant Treasurer.

F. P. McKibben
Re-elected President A. W. S.

Officers of the Bureau Re-elected

The following officers of the American Bureau of Welding were re-elected to serve for another year:

Director—C. A. Adams
First Vice-Director—H. M. Hobart
Second Vice-Director—J. H. Critchett
Secretary—W. Spraragen

Director C. A. Adams, with the approval of the Bureau, appointed the following members to act as an Executive Committee for the coming year:

Chairman—C. A. Adams
Secretary—W. Spraragen
J. H. Critchett, J. J. Crowe, J. H. Deppeler, F. M. Farmer, H. M. Hobart, C. A. McCune, F. P. McKibben, L. S. Moisseiff and E. M. T. Ryder.

Obituary

It is with very great regret that we are obliged to announce the passing away on Sunday, April 9th, of Lee H. Miller, Chief Engineer of the American Institute of Steel Construction, at St. Luke's Hospital in Cleveland.

Mr. Miller had been ill since the first part of January and recently had two surgical operations performed and it was found that he could not recover.

It was through the vision and imagination of Mr. Miller that the American Institute of Steel Construction was brought into being. His contributions to the engineering profession and to the structural steel industry have been many and of great importance. His thousands of friends and admirers throughout the United States and Canada, as well as in some foreign countries, have looked upon Mr. Miller not only as a great engineer but as a man of outstanding ability and character.

Mr. Miller has served on the Structural Steel Welding Research Committee and has been active in advancing the cause of structural steel welding.

Fall Meeting

The Fall Meeting of the AMERICAN WELDING SOCIETY will be held in Detroit during the week of October 2nd in connection with the Metal Congress. The Meetings and Papers Committee invites the suggestions of all the members of the Society for papers to be presented at this Fall Meeting. These suggestions should be sent in at once. Every effort will be made to have the Fall Meeting truly represent the desires of a cross section of the members of the AMERICAN WELDING SOCIETY.

Report of the President for the Year Ending March 31, 1933

(This report was presented at the Annual Meeting of the Society, April 28, 1933.)

As prescribed by the by-laws, the following report covering the activities of the Society for the administrative year ending March 31, 1933 is here submitted:

Membership.—For the second time in the history of the Society, the curve of growth of membership has turned downward, which of course is not unlike conditions prevailing in all other scientific and technical societies.

At the close of the fiscal year the total membership was 1284, representing a net loss of 90 members during the year. Actually we secured 151 new members and lost 241. Unfortunately, the greatest loss was in the Sustaining and Member grades, which was due to present business conditions. In every case an effort was made to get these members to retain membership in lower grades, and to some extent this met with success.

Consideration was given by the Membership Committee to various means of securing new members. Several test trials involving small sums of money indicated it was not feasible to obtain members during the past year. A plan for solicitation of membership on a large scale was

proposed. This included method of financing. However, as the sum pledged for carrying on the work was not sufficient to carry on entire cost of campaign, it was deemed necessary to modify plan so as not to incur expenses beyond sum pledged for this work. It is the hope that conditions will be more favorable during the coming year for going ahead with this work.

Class		Membership			
		1930	1931	1932	1933
(*A*)	Sustaining members	44	40	33	21
(*B*)	Members	498	443	403	350
(*C*)	Associate members	476	615	639	613
(*D*)	Operating members	279	273	257	261
(*E*)	Honorary members	3	3	2	2
(*F*)	Student members	43	50	40	37
	Total	1343	1424	1374	1284

Sections.—No new sections have been organized during the year, although numbers of inquiries have been received from various industrial centers in regard to the formation of sections. Effort is being made to build up membership in these localities so that at the proper time sections can be organized.

Attempt has been made to revivify interest in the Western New York and Canadian Sections, but the time was found inopportune. In both instances it was felt that just as soon as business picks up, live sections can be developed.

Our present sections, with a few exceptions, have been active during the year. Most of them have held meetings fairly regularly. Special mention should, however, be made of the interest displayed in Society affairs by the officers and committees of the sections on the West Coast, of the session sponsored by the Detroit Section during the Highway and Building Congress last January and of the outstanding meetings arranged by the Philadelphia and New York Sections.

The majority of our sections have again responded generously to our request that they renew this year arrangement for refund in effect last year. The spirit of the sections in accepting this arrangement is certainly most appreciated.

Finances.—The total receipts during the Society year ending March 31, 1933 were $26,002.08.

The corresponding disbursements were $27,721.30 which, as compared to Society year ending March 1932, shows a decrease in receipts of $8896.80, and a decrease in disbursements of $5778.48.

The Society's cash balance at the time of closing the books March 31, 1933 was $1329.86 or a decrease in cash balance from that of closing the books on March 31, 1932 of $1719.22. In addition to the above there was on hand in a separate bank $501.77 covering the Miller Memorial Medal Fund. The value of salable printed matter on hand was $2500 as against a like amount at the close of the books on March 31, 1932.

The present worth of your Society as of March 31, 1933 is $4461.42 as against $7021.27 on March 31, 1932, or a decrease in worth of $2559.85. This is accounted for as follows: loss in market value of investment in St. Louis-San Francisco Railway Company Bonds $660; net loss in operation of $1747.30 and provision in depreciation of office equipment, $152.55.

A more detailed financial statement will be presented to the directors at this Annual Meeting. It will also be published in the Society Journal and there is on file at Society Headquarters the usual Annual Report of the Certified Public Accountant dated April 17, 1933.

Journal.—Considerable attention was devoted this year to improving the Journal and enlarging its scope of usefulness. The principal purpose was to include articles of interest to a larger number of people representing foremen, inspectors and welders. A number of new departments were added to the Journal and still others will be added from time to time.

The 1932 bound volume, the second to appear in its present size, includes 608 printed pages including covers. This contrasted with 788 printed pages for the year 1931. An approximate division for the material published in 1932 is: editorial, 32; technical, 401; advertising and standing matter, 175.

Although the Journal of the Society continues to pay for itself, if due consideration is given to returns from advertising, subscriptions and bound volumes, the margin of profit was reduced. The reduction in number of pages has been necessitated by lessened income brought about as a result of reduction in advertising. A still further reduction will probably be found necessary for the first half of 1933, at least. With a return to normal conditions it should be possible to increase the size of the Journal and improve its quality. As in other years, technical reports, results of research work, codes, standards and specifications have been featured.

Meetings.—As usual, two meetings of the Society were held, the Annual Meeting in New York in April, and the Fall Meeting in Buffalo on October 3rd to 7th, with a registered attendance of 250. Both were successful in spite of the adverse business conditions.

At the Annual Meeting some very fine technical sessions were held, the principal one being that on Ductility of Welds. In addition, meetings of the American Bureau of Welding, Structural Steel and other committees were held. The Annual Dinner held at the Hotel New Yorker was a stag affair.

As in previous years the Fall Meeting was held in conjunction with the National Metal Congress and Exposition. It is interesting to note that the welding exhibits this year totalled about 20% of the entire exposition. Some 25 technical papers were presented at the Fall Meeting, outstanding among these were the ones dealing with welding applications in the machinery industry, gas cutting, results of research work, welding of non-ferrous metals, merchandising, qualification of welders, pressure vessels, structural steel and new welding developments in apparatus and materials. At this meeting, the Miller Memorial Medal was presented to Professor F. P. McKibben for his outstanding achievements in structural steel welding. The registered attendance was 188.

Changes in By-Laws.—The following changes in by-laws received the majority approval of the membership by letter ballot:

Art. IV. Sect. 3.—A senior Vice-President shall be elected by the Society for a term of one year and may be re-elected at any time for a second term of one year, but in no case shall any individual serve in this capacity for more than two consecutive years.

Art. IV. Sect. 5—Par. 3.—At each Annual Meeting the Society shall elect five Directors-at-large to serve for a term of three years.

Art. IV. Sect. 5—Par. 4.—The officers and the three junior Past-Presidents shall automatically be members of the Board of Directors.

Society Committees.—During the year the committee assigned the task of preparing Standards on What Should be Known by a Welding School Graduate completed its work. The report was published in the Society Journal, and the committee discharged with thanks.

The Committee on Welding Code for Pressure Vessels, having fulfilled the purpose for which it was appointed by the formulation of welding rules contained in the 1931 edition of the A. S. M. E. Boiler Code, was discharged with thanks.

Several new committees have been appointed to cover the following assignments:

Cooperating in planning suitable demonstration of welding processes for proposed Rosenwald Museum of Science and Industry in Chicago.

Criticism and comments on proposed Welding Rules, U. S. Navy General Specifications for Machinery.

Development of Standards for Construction of Underground Oil Storage Tanks and Inside Tanks for Oil Burning Equipment. This committee prepared a report which was approved by the Executive Committee and transmitted to the National Fire Protection Association Flammable Liquids Committee.

Representatives on A. S. A. Sectional Committee undertaking Development of Ventilation Code have also been appointed.

Committee to Study Welding of Highway and Railway Bridges with a view to preparing a set of specifications covering this work has been authorized. Considerable thought and attention is being given to the best qualified men to serve on this committee. For obvious reasons the selection of personnel cannot be done hurriedly.

A brief review of work covered by our other committees is as follows: Complete reports are on file in the Society office.

Committee on Building Codes.—Three meetings of the Main Committee were held in New York and a meeting is in plan during the coming Annual Meeting. In addition a number of meetings of sub-committees were held:

Code for Resistance Welding of Structural Steel.—A supplemental engineering committee has been appointed to determine suitable structures and scope of parts to be embraced by the initial issue of the resistance welding code. Preliminary recommendations of this committee were considered and it is expected that the final draft will be prepared shortly for consideration of the main committee. Upon the determination of the proper scope of the code, the Sub-Committee on Resistance Welding will be asked to prepare the necessary code.

Code for Welding Low Pressure Tankage.—This sub-committee is awaiting a report from the Flammable Liquids Committee of the National Fire Protection Association who is studing the whole problem of low pressure tankage.

Code for Welding Low Pressure Piping.—This sub-committee is awaiting the promulgation of the A. S. M. E. Code for Pressure Piping in order to determine whether a low pressure code is necessary and desirable.

Code for Fusion Welding of Structural Steel.—The recommendation that the use of linseed oil in the painting of structural steel to be welded be made permissive instead of mandatory and to omit reference to number of coats of paint required was adopted and cited for inclusion in the next edition of Code 1, Part A. The revision was published in the June issue of the Journal.

The committee recognizes that a general revision of Code 1, Part A will soon have to be undertaken in order that its text will be in keeping with the progress in applied structural welding in this country since the last edition. These changes will include welding wire specifications, nomenclature for structural welding, qualification of welders and recommendation as to the technique of welding.

Construction Safety Code.—The committee is awaiting report of the sub-committee.

New York City Building Code.—A printed draft of the new code was submitted to the Board of Aldermen November 22, 1932, by Mayor McKee. It was then referred to the Building Committee of the Board of Aldermen for study and public hearings. No public hearings have been held as yet.

Committee on Use of Welded Steel Parts for Machinery Construction.—Several meetings of the committee have been held during the year; its report is now completed and is to be presented at the Thursday afternoon session of this Annual Meeting. It is felt that this report will go far toward meeting the need for standards covering basic welded machinery design.

A joint committee of the A. S. M. E. and our Society on Machinery Construction has been proposed, and it is the intention to proceed with the formation of such committee immediately following the publication of our committee's report.

Committee on Welding Code for Pressure Piping.—During the year the committee has actively cooperated with the A. S. M. E. Sectional Committee on a Code for Pressure Piping. Meetings were held in April and June 1932 at which the tentative welding code was considered and a few minor changes adopted, particularly in the nature of clarification. To meet requests received at headquarters, the latest draft was mimeographed for limited distribution.

A meeting was held on March 30, 1933 at which the Code was carefully reviewed for the purpose of presentation at the Annual Meeting. A few minor changes were adopted:

It is the plan of the committee to re-mimeograph this latest revision of the Code both for public presentation at the Spring Meeting and submission to the Executive Committee for official transmission to the American Society of Mechanical Engineers. These steps, it is hoped, will successfully complete the original duty and cooperative efforts of the committee to assist the American Society of Mechanical Engineers in the formulation of a code.

Due to questions of policy and apparent unwillingness of the American Society of Mechanical Engineers to officially sanction the issuance of a separate code by the AMERICAN WELDING SOCIETY, at least before final printing of the American Standards Association Code, the Executive Committee decided to defer publication of a separate Society code until the issuance of the A. S. A. Pressure Piping Code.

Committee on Welding in Marine Construction.—The sub-committees on boilers and unfired pressure vessels, under the chairmanship of Dr. D. S. Jacobus has not only maintained a close contact with the U. S. Steamboat Inspection Service, but has brought its work up to date. It is hoped to submit the latest revisions of these "Rules" to the Board of Directors for their approval at the annual meeting.

The Hull sub-committee, under the chairmanship of Mr. C. W. Bryan, Jr., appointed a "Working sub-committee" under the Chairmanship of Mr. G. H. Moore. This Working sub-committee has been actively engaged in the preparation of hull rules, and has made considerable progress. Mr. Bryan hopes to have these rules in such shape that they can be presented to the entire Marine Committee for its approval at an early date.

Committee on Revision of Nomenclature, Definitions and Symbols.—A sub-committee for the preparation of structural symbols was organized just prior to the Fall Convention. The report of this committee was submitted to the entire membership of the Main Committee, and final drawings are now being prepared. It is hoped to submit this report to the Board of Directors at the Annual Meeting.

The Chairman of the committee has worked closely with Mr. A. V. Bouillon, secretary of the Marine Standards Committee, in the preparation of a re-draft of the Marine Symbols, and it is hoped that these will be in such shape that they can also be presented to the Board of Directors at the Annual Meeting. It is of interest to note that the present A. W. S. Marine Symbols were submitted by Mr. Bouillon to the membership of the American Marine Standards Committee and its approval secured.

Mr. H. W. Samson, Chairman of the sub-committee on Classification for Welding, advises that considerable progress has been made. He hopes to have his report completed in the near future.

The nomenclature used in the various A. W. S. and A. S. M. E. welding codes now under preparation has been carefully reviewed from time to time.

Committee to Prepare Manuscript for Revised Arc-Welding Manual.—A meeting of this committee was held during the 1932 Annual Meeting. Several chapters have been revised. Last September consideration was given to the advisability of continuing this work in view of the fact that N. E. M. A. had just published an Electric Arc-Welding Manual, The Executive Committee having in mind that it would take our committee about a year to complete its work, instructed the committee to proceed with the revision of our Arc-Welding Manual.

Legislative Committee.—During the past year this committee has given attention to and acted on the following matters:

San Francisco—Proposed Boiler Inspection and Fee Ordinance

Michigan State Highway Dept.—Bill pertaining to use of flame cutting in structural steel shapes for bridge fabricating purposes.

Oregon Bill relative to Licensing of Welders.

Pennsylvania S. B. pertaining to Protection of Welders and others from harmful rays.

New York Assembly bill relative to Licensing of Mechanic Welders.

Convention Committee.—Two meetings of the committee were held in which it was agreed to recommend that the Society participate in the 1933 National Metal Congress and Exposition to be held in Detroit, the week commencing October 2nd, providing our Society could be guaranteed by the A. S. S. T. a minimum of $500 to cover our Fall Meeting expenses. Notification has been received from the Secretary of the A. S. S. T. that our Society will be allowed the usual 15% return on all welding space sold, with a $500 minimum guarantee.

The Committee after careful consideration, recommended that our headquarters

during the Fall Meeting be at the Book-Cadillac Hotel.

Board of Trustees Miller Memorial Medal.—The Chairman of the Board reports as follows: The Committee has decided that the 1932 Samuel Wylie Miller Memorial Medal should be given this spring to Mr. Herbert H. Moss of the Union Carbide & Carbon Corp. for his achievements in the application of fusion welding and flame cutting.

American Bureau of Welding.—The Bureau has published a number of reports during the year as follows:

"Concerning Crater Formation," by Gilbert E. Doan, July.
"On the X-ray Determination of Stresses in Welds," by J. T. Norton, Sept.
"Metal Deposition in Electric Arc Welding," by G. E. Doan and J. Murray Weed, Sept.
Final Report of Welded Rail Joints Committee, Sept., 358 pages.
"A Corrosion Fagitue Study of Welded Low-Carbon Steel," by W. E. Harvey and F. J. Whitney, Oct.
"Distribution of Stresses in Welded Double Butt Strap Joints," by S. C. Hollister and A. S. Gelman, Oct.
"Researches in Arc Welding," by G. E. Doan and J. L. Myer, Nov.
"Fundamental Research Bulletin," Feb. 1933, 27 pages.

Welded Rail Joints.—E. M. T. Ryder, Vice-Chairman. The Committee is to be congratulated for its Final Report published in September 1932 summarizing the results of a ten-year program of investigations seeking to improve and standardize the making of welded rail joints. The special pieces of apparatus developed, the new methods of testing and the test results will all be of interest and importance to other industries. The investigation involved cooperative research on a wide scale and the making and testing of literally thousands of specimens. The report indicates that some forty companies contributed funds, materials, equipment, apparatus and test specimens, and ten laboratories assisted in the investigational work.

Welding Wire.—C. A. McCune, Chairman. Numerous conferences and committee meetings have been held during the year in an endeavor to revise the Specifications on Welding Wire so as to take in account the latest developments. The revised Specifications approved by the Executive Committee of the Bureau are based entirely on the properties of the welded joints obtainable with the various types of welding wire. The old specifications referred largely to the composition and physical properties of the welding wire itself. Recent advances in the art and multiplication of the means for obtaining superior welds make the old system of specifications no longer possible. This fact coupled with the recent trend in various codes to specify by ultimate result rather than intermediate means has led the Committee to adopt that method.

Structural Steel.—Leon S. Moisseiff, Chairman. This Committee has marked time during the year. It developed a program of additional investigations but reactions from experts in the field indicated that possibly other data might be needed. The Committee has awaited the crystallization of opinion in the matter in order to conserve its limited resources which permit only the conduct of a limited program of investigations.

Fundamental Research.—H. M. Hobart, Chairman. A bulletin published by this Committee in February of this year indicated some forty specific investigations which are now under way in the various university and governmental laboratories. The Committee has made a serious attempt to analyze some of the problems in the welding field which need solution. A conference of professors interested in fundamental research was held in Buffalo in connection with the Fall Meeting of the Society. The purposes of the conference were (*a*) to stimulate fundamental research work in the welding field at our leading universities; (*b*) to provide an opportunity for the interchange of ideas between the active research workers in this field; (*c*) to discuss their problems with scientific workers in industry; (*d*) to develop ways and means for expediting research progress either through the formulation of problems selected for study or in arrangement for supply of materials and apparatus that might be needed; (*e*) to permit the professors to attend the sessions of the AMERICAN WELDING SOCIETY and the exposition on welding in order that they might familiarize themselves with the latest industrial advances. An appropriation of $450 was made by the Grant-in-Aid Committee of the National Research Council to defray the railroad, pullman and incidental traveling expenses of the professors to this conference.

Satisfactory progress has been made by the local sub-committees in Boston, New York and Pittsburgh in furthering fundamental research in each of these localities.

Serious attempts were made by the chairman of the main committee in initiating library researches on specific subjects in the welding field. It is hoped that these efforts will be fruitful of results during the coming year.

Representation on Other Societies.—During the past year the Society, through its representatives, has continued to participate in the activities of the following organizations: A. S. M. E. Boiler Code Committee, A. S. A. Sectional Committees on Electrical Definitions, Electric Welding, Sub-Committee No. 6 on Graphical Symbols for Drawings, Standardization of Electric Welding Dies and Electrode Holders, Safety Code for Construction Work A-10, Safety Code for High Pressure Piping; A. E. R. E. A. Committee No. 6 on Standard Specifications for Welding Rods; American Marine Standards Committee; A. S. S. T. Recommended Practice Committee; Advisory Committee of Merchants Association on Revision of New York City Building Code; Executive Board of National Board of Boiler and Pressure Vessel Inspectors; Committee to confer with National Board of Fire Underwriters; A. S. T. M. Welding Wire Specifications Committee and Sub-Committees of A. S. T. M. on Specifications for Fusion Welding, and on Wrought Copper and Copper Alloys. Space does not permit me to give a detailed account of all of these activities, although such accounts may be found in the files of the Society by any one interested. Special recognition should, however, be given the work of our Conference Committee which cooperates with the A. S. M. E. Boiler Code Committee in formulating replies to inquiries that have arisen in connection with applications of the code rules to welded pressure vessels. During the past year the committee acted on four matters. Reports were prepared, and after their approval by our Executive Committee, these were transmitted to the Boiler Code Committee. Of special note also is the assistance rendered by a special committee of our San Francisco Section to the Pacific Coast Building Officials Conference in the preparation of the welding section of the new Pacific Coast Building Code.

Miscellaneous Appointment.—Professor Adams was designated to prepare testimonial and attend dinner in commemoration of the eightieth birthday of Professor Elihu Thomson on March 29, 1933.

Recommendations.—It is my belief that our efforts at this time should be concentrated on building up the membership of the Society. Through a larger membership the circulation of the Journal will be increased, thus enabling us to secure additional advertising, which in turn will make possible a larger and better Journal. There are many industrial centers where the use of welding should be extended, and others where welding could be effecting greater savings. In these localities there is opportunity for missionary work, and in such localities there is a splendid opportunity to get members, and in some instances, establish sections of the Society.

The Society is, and should be, looked upon as the authoritative body in the welding field. Its potential possibilities of services to the welding industry are numerous. Other technical and scientific bodies are turning to it more and more for assistance in matters pertaining to welding. A complete disruption of our activities at this time would be very unfortunate. What we need most are new members, particularly among the users. Much can be accomplished in this direction if each of our Divisional Vice-Presidents and every member of the Board of Directors and Executive Committee would be willing to assist the Membership Committee in its efforts, and would make himself responsible for getting in new members. The manufacturing companies too could help by rallying to the support of the Society through liberal appropriations for advertising in the Journal.

Conclusions.—In concluding, I wish to express my appreciation for the splendid response received from our sustaining members in prompt payment of dues. I wish also to thank our regular advertisers in the Journal for their continued support, and the national officers, committee members, Section officers and the membership-at-large for their cooperation and assistance during the past year.

Erecting Steel Buildings and Strengthening Steel Bridges by Welding

By FRANK P. McKIBBEN

†A lecture presented at the Annual Meeting, American Welding Society, April 27–28, 1933, by Frank P. McKibben, Consulting Engineer.

PART I

Governmental Control of the Welding Industry Undesirable

SEVERAL legislative bills are now under consideration for additional restriction to the art of welding. These take the form of proposals to license welders by state governments or to protect the eyes of workmen and others from the harmful rays of electric and acetylene welding operations by enclosing the welder.

If licensing by municipal, state or the national government would appreciably expedite building or bridge construction, reduce construction costs to owners, result in more nearly continuous employment for capable welders, and secure safer structures, it may be desirable; but I much prefer to have the responsibility for welding placed where it belongs, on the welding contractor rather than on the individual workman. Governmental supervision often results in restriction and delays, not in expediting work, tending to increase not decrease the cost of construction. Nor can I see any reason for demanding greater safety in welded structures for they are already provided with sufficient safety as shown by the entire absence of failure in any of the several hundred welded buildings, and by only one partial failure in welded bridges in the United States. But licensing is "in the air" and unless those concerned with welding tanks, buildings, bridges offer some practical solution for licensing welders, I fear an *X* number of states, or *Y* number of cities, will adopt some machinery for accomplishing this.

Welding and the Building Codes

The one hundred twenty-nine municipalities listed in Table 1 are known to have incorporated, in their building codes, permission to use welding in steel building frames. New Orleans with a population of 456,000 is the largest city in the list; Cincinnati, the last to be included. Practically all of these municipal codes are based on that of the AMERICAN WELDING SOCIETY.

The New York Merchants Association has prepared and has presented to the city for adoption, a new building code which includes welding and gas cutting provisions. Chicago's new code is progressing toward adoption. Boston, Los Angeles and San Francisco have authorized welded buildings under special permits.

Out of the chaos of municipal building codes some light is visible in movements such as those endeavors to secure uniform building codes being made by the New England Building Officials Conference, the Provincial Government of Ontario, and California State Chamber of Commerce in cooperation with the Pacific Coast Building

Table 1—One Hundred Twenty-Nine Towns and Cities Which Have Included Welding in Their Building Codes

Alabama
- Birmingham

Arizona
- Phoenix
- Prescott
- Tucson
- Yuma

Arkansas
- Eldorado

California
- Alameda
- Alhambra
- Alturas
- Anaheim
- Berkeley
- Bell
- Brawley
- Burbank
- Calexico
- Claremont
- Compton
- Corcoran
- Coronado
- Davis
- El Centro
- El Monte
- El Segundo
- Escondido
- Fontana
- Fresno
- Fullerton
- Gardena
- Hawthorne
- Huntington Park
- Imperial
- Inglewood
- Laguna Beach
- La Habra
- Livermore
- Long Beach
- Lynwood
- Madera
- Martinez
- Maywood
- Modesto
- Monrovia
- Monterey Park
- Mountain View
- National City
- Newport Beach
- Oceanside
- Ontario
- Orange
- Palo Alto
- Pasadena
- Petaluma
- Piedmont
- Pittsburg
- Pomona
- Redlands
- Richmond
- Riverbank
- Riverside
- Sacramento
- San Anselmo
- San Bernardino
- San Bruno
- San Diego
- San Fernando
- San Jose
- San Leandro
- San Luis Obispo
- San Rafael
- Santa Maria
- Santa Monica
- Seal Beach
- Sebastopol
- Sierra Madrea
- South Gate
- South Pasadena
- South San Francisco
- Stockton
- Sunnyvale
- Tracy
- Tujunga
- Tulare
- Turlock
- Tustin
- Ukiah
- Upland
- Visalia
- Walnut Creek
- Watsonville
- Willow Glenn

Colorado
- Grand Junction

Delaware
- Wilmington

Iowa
- Davenport

Louisiana
- Shreveport
- Monroe
- New Orleans

Massachusetts
- Lynn
- Pittsfield

Mississippi
- Meridian

Montana
- Helena

New Hampshire
- Manchester

North Dakota
- Grand Forks

New Jersey
- Chatham

New Mexico
- Albuquerque

New York
- Jamestown
- Rochester
- Syracuse
- Utica

Nevada
- Las Vegas

Ohio
- Cincinnati
- Youngstown

Oregon
- Cottage Grove
- Eugene
- Klamath Falls
- Marshfield
- Medford
- Portland
- Salem

Pennsylvania
- Erie

Texas
- Houston
- Austin
- Corpus Christi
- Dallas

Washington
- Ellensburg
- Everett
- Kelso
- Olympia
- Yakima

Wyoming
- Cheyenne

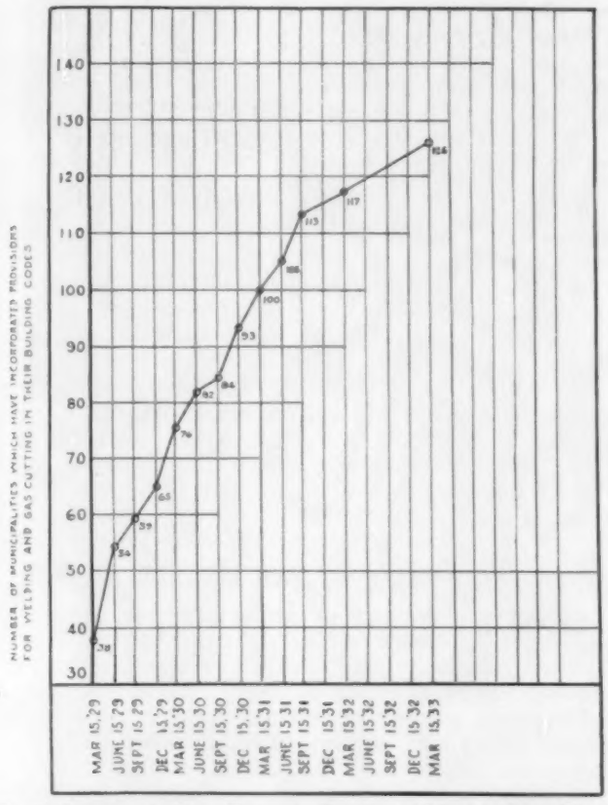


Fig. 1—Increase, in Four Years, in Number of Municipalities Which Have Incorporated, in Their Building Codes, Provisions for Welding Steel Building Frames

Officials Conference, each working in its respective district to produce uniform building codes.

Judging from the extension of welding during the last five years the time will soon arrive when the skepticism binding a few steel fabricators and a few municipal building commissioners will disappear, as Longfellow's

> "Cares that infest the day
> Shall fold their tents like the Arabs,
> And as silently steal away."

Except in those states where adoption by reference is prohibited by state statutes, I see no reason for cluttering up municipal ordinances with long wordy details of welding. The following is sufficient:

> "Electric arc and oxyacetylene welding may be substituted for or used in combination with riveting, bolting or other requirements described elsewhere in this code for connecting together or assembling the component parts of steel beams, girders, lintels, trusses, columns or other structural steel used in building construction, provided that the welding be done in accordance with the 'Code for Fusion Welding and Gas Cutting in Building Construction' edition of 1930, of the AMERICAN WELDING SOCIETY, and as amended to date by said Society."

If something more elaborate is thought necessary, the Rochester, N. Y., code's provisions are ample as shown by Articles 8 and 9 of Section 807:

> "8. Welding. (*a*) Nothing in this ordinance shall prohibit the use of arc or gas welding in the erection of steel construction in lieu of riveting or bolting.
>
> "(*b*) Surfaces to be welded shall be free from loose mill scale, rust, paint or other foreign matter.
>
> "(*c*) Surfaces to be welded shall not be painted before they are welded. Parts that are welded in the shop, to be erected by bolts or rivets in the field, shall receive the usual painting after the shop work is completed.
>
> "(*d*) The edges of base metal parts, one-quarter of an inch or more in thickness, transmitting stress by means of butt welds shall be beveled, the bevel of each part being not less than thirty degrees.
>
> "(*e*) Steel construction which is to be welded in the field shall be temporarily supported and properly aligned by erection bolts or other efficient means before the field welding is done.
>
> "(*f*) Except as otherwise specifically provided in this ordinance or in rules duly promulgated by the superintendent of buildings, the Code for Fusion Welding and Gas Cutting in Building Construction, as adopted and amended from time to time by the AMERICAN WELDING SOCIETY, shall be deemed to be the generally accepted good practice in welding and gas cutting.
>
> "9. Gas cutting. (*a*) Nothing in this ordinance shall prohibit gas cutting in steel construction; provided that gas cutting shall not be done on a member while it is under stress, and that it is not done where the milling of surfaces is required for proper workmanship.
>
> "(*b*) Gas cutting edges shall be smooth and regular in contour, and when used in the preparation of base metal parts for welding, shall be thoroughly cleaned to expose only clean metal.
>
> "(*c*) Gas cutting of holes in a member which has not been designed therefore shall not be done."

Importance of Theory

Wonderfully inspiring is the application of mathematics and theoretical mechanics to the solution of practical problems, to the creation of machines and structures. The engineer's mind conceives the structure, perhaps dimly at first, but as the conception assumes more definite form, his creative ability aided by mathematics and structural mechanics, translates the mental picture into drawings and specifications enabling others to crystallize his dream into material forms—into steel machines, steel buildings, steel bridges.

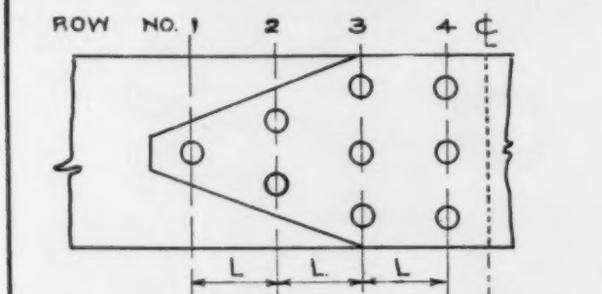
As he beholds the product of his imagination, then comes the satisfaction, not of having built an inspiring monument to his own skill, but in having created a structure to aid his fellowmen, to lighten their burdens and make their paths through life happier.

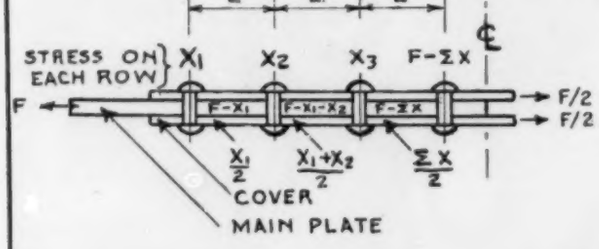
Junius in one of his letters of 1770 implied this satisfaction resulting from accomplishment when he said, "The heart to conceive, the understanding to direct or the hand to execute." And Daniel Webster's oration at Bunker Hill in 1825 expressed the wonderful power of mental processes, "Mind is the great lever of all things; human thought is the process by which human ends are ultimately answered."

I know of no greater pleasure than aiding creative effort with mathematics and the theory of mechanics. And much do I regret having failed so often to inspire students with the importance of theory. With apologies to Horace Greeley, I would say, "Young man, go not West. Instead, learn theory and how to apply it."

Stresses in Riveted and in Side-Welded Joints

A completely satisfying analysis of stress distribution in riveted and in side-welded joints has not yet been presented; nor am I able to offer anything better than those already presented. But some beautiful studies have





n ROWS OF RIVETS
m_1 RIVETS IN FIRST ROW– m_2 IN SECOND
m_n RIVETS IN LAST ROW
A CROSS SECTION OF MAIN PLATE
$A_1'/2$ MEAN SECTION EACH COVER BETWEEN FIRST & SECOND ROWS.
$A_2'/2$ MEAN SECTION EACH COVER BETWEEN SECOND & THIRD ROWS.

FOR A BAR OF LENGTH L, SECTION A, MODULUS E,
WORK DUE TO TENSION = FORCE × ELONGATION
$= S \times SL/AE$
$= S^2L/AE$

WORK IN ELONGATING MAIN PL. BETWEEN FIRST & SECOND ROWS $= (F-X_1)(F-X_1)L/AE = (F-X_1)^2L/AE$

" SECOND & THIRD ROWS $= (F-X_1-X_2)^2L/AE$

WORK IN ELONGATING TWO COVERS BETWEEN FIRST & SECOND ROWS $= 2\left[2r_1(X_1/2)^2L/A_1'E\right]$

" SECOND & THIRD ROWS $= 2\left[2r_2\left(\frac{X_1+X_2}{4}\right)^2L/A_2'E\right]$

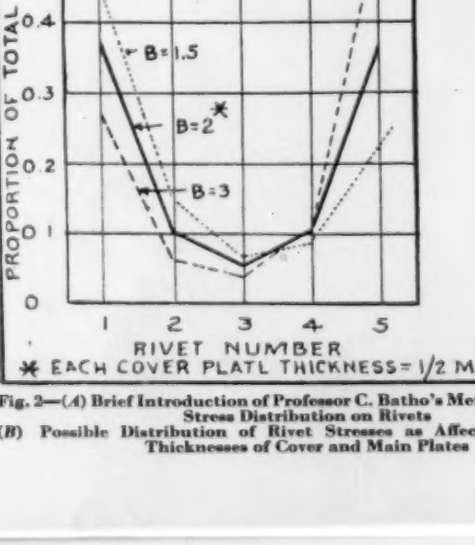
WORK IN DEFORMING RIVETS IN FIRST ROW $= k\,m_1(X_1/m_1)^2/E$

" SECOND ROW $= k\,m_2(X_2/m_2)^2/E$

$$\underline{\text{WORK}} = \frac{L}{2AE}\left[(F-X_1)^2+(F-X_1-X_2)^2+\cdots+(F-\Sigma X)^2\right]$$
$$+\frac{L}{E}\left[\frac{2r_1}{A_1'}\left(\frac{X_1}{2}\right)^2+\frac{2r_2}{A_2'}\left(\frac{X_1+X_2}{2}\right)^2+\cdots+\frac{2r_{n-1}}{A_{n-1}'}\left(\frac{\Sigma X}{2}\right)^2\right]$$
$$+\frac{k}{2E}\left[m_1\left(\frac{X_1}{m_1}\right)^2+m_2\left(\frac{X_2}{m_2}\right)^2+\cdots+m_n\left(\frac{F-\Sigma X}{m_n}\right)^2\right]$$

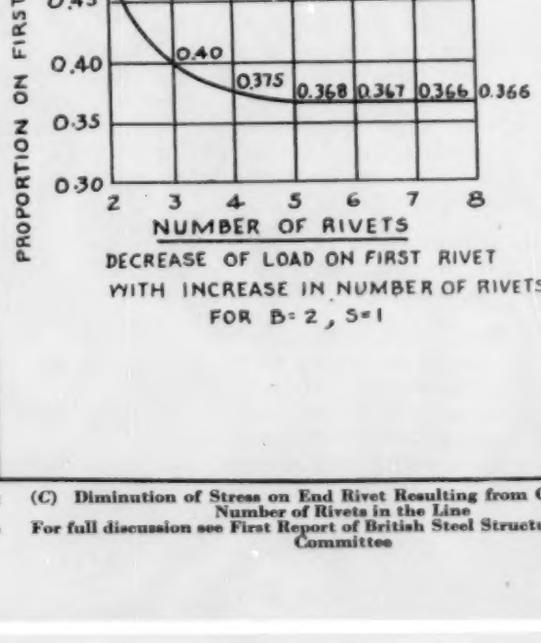
BUT $\frac{dW}{dX_1}=0$ ETC.

A



* EACH COVER PLATE THICKNESS = 1/2 MAIN PL.

B



DECREASE OF LOAD ON FIRST RIVET WITH INCREASE IN NUMBER OF RIVETS FOR B = 2, S = 1

C

Fig. 2—(A) Brief Introduction of Professor C. Batho's Method of Studying Stress Distribution on Rivets
(B) Possible Distribution of Rivet Stresses as Affected by Relative Thicknesses of Cover and Main Plates
(C) Diminution of Stress on End Rivet Resulting from Changing the Number of Rivets in the Line
For full discussion see First Report of British Steel Structures Research Committee

come from Messrs. Batho,[1] Weiskopf,[2] Male,[2] Troelsch[3] and Hrennikoff.[4]

Two methods of attacking these problems have been used. In one, the determination of stress distribution is based on the principle of mechanical work, commonly called the principle of least work. The other method utilizes deformations or displacements in deducing equations. Riveted as well as side-welded joints are statically indeterminate structures; that is, in order to solve the various unknown quantities, one must resort to the theory of elasticity, including the principle of least work or a study of deformations, to secure the equations required in addition to those of statics, so that the number of independent equations shall equal the number of unknown quantities, no more and no less.

In practically all studies thus far published, assumptions are made which may affect the results materially. Some of these are: (*a*) deformations are proportional to stresses, in other words, that joint deformations follow Hooke's law; (*b*) that stress is uniformly distributed over any given cross section of each bar.

In using formulas derived on the assumption that stress is proportional to strain, care must be taken not to apply them to cases where the stresses are beyond the proportional limit, a process of reasoning which frequently leads to the conclusion that portions of the joint are stressed quite beyond the elastic limit and near the breaking point. Of course, if stress at any point reaches such a high value, the deformation at that part is greater than was assumed in deriving the formula, hence that particular formula is inapplicable, and a new one is necessary.

Principle of Least Work

Mechanical work, or strain energy, is force times distance through which the force acts. Briefly, the principle of least work is that a body acted upon by an external load so deforms that the total work is a minimum.

For a bar with length L and cross section A, modulus of elasticity E, subjected to direct total tension or compression of S, the work done in lengthening or shortening is S^2L/AE. Professor Batho has applied this principle to study stresses in riveted and in welded joints. Without attempting to give the entire study the following is illustrative of the method of attack: in Fig. 2*A* the unknown forces on the various rivet rows are represented by X_1, X_2, etc.; F is the total load on the joint; n the number of rows of rivets; m_1 the number of rivets in the first, m_2 in the second, m_n in the last row; L the pitch; A cross-sectional area of main plate; $A'_1/2$ mean cross-sectional area of each cover plate between first and second rows of rivets, $A'_2/2$ between the second and third rows of rivets, etc.

Now the work done in stretching the main plate between first and second rows is $(F - X_1)^2L/AE$, and between the second and third $(F - X_1 - X_2)^2L/AE$, etc. Similarly the work of two cover plates between the first and second rows is $2[2r_1(X_1/2)^2L/AE]$; and between the second and third rows is $2[2r_2(X_1 + X_2)^2L/4\,A'_2E]$, etc.; where r_1, r_2, etc., are ratios between the work done in the cover plate to that done in a plate of same length but of uniform cross section. Finally the work of deforming the rivets in the first row is expressed as $km_1(X_1/m_1)^2/E$; in the second row by $km_2(X_2/m_2)^2/E$, etc., where k is a factor to be determined experimentally. If one could determine the bending moment in the rivet, the work due to bending would be $\int M^2/EI$, which in long rivets may be appreciable. But in this study the factor k is supposed to be embracing.

Assembling the work of main plate, two splice plates and of all rivets, the entire work of the joint is:

$$\text{Work} =$$

$$\frac{L}{2AE}\left[(F-X_1)^2+(F-X_1-X_2)^2+\ldots+(F-\Sigma X)^2\right]$$

$$+\frac{L}{E}\left[\frac{2r_1}{A'_1}\left(\frac{X_1}{2}\right)^2+\frac{2r_2}{A'_2}\left(\frac{X_1+X_2}{2}\right)^2+\ldots+\frac{2r_{n-1}}{A'_{n-1}}\left(\frac{\Sigma X}{2}\right)^2\right]$$

$$+\frac{k}{2E}\left[m_1\left(\frac{X_1}{m_1}\right)^2+m_2\left(\frac{X_2}{m_2}\right)^2+\ldots+m_n\left(\frac{F-\Sigma X}{m_n}\right)^2\right]$$

Since, according to the principle of least work, the total work on the system is a minimum, $dW/dX_1 = 0$; thus, by differentiating in turn with respect to each of the unknowns, sufficient equations are secured to solve.

Professor Batho presents, Fig. 2*B* and *C*, some interesting studies of riveted joints; and then extends the study to side-fillet welds, showing how rows of rivets as well as side fillets are affected by the same disease; nonuniformity of stress distribution.

Mr. Hrennikoff,[5] by attacking the problem with deformations, also shows a lack of uniformity of stress in a line of rivets parallel to the stress.

[5] Proceedings of A. S. C. E., Nov. 1932.

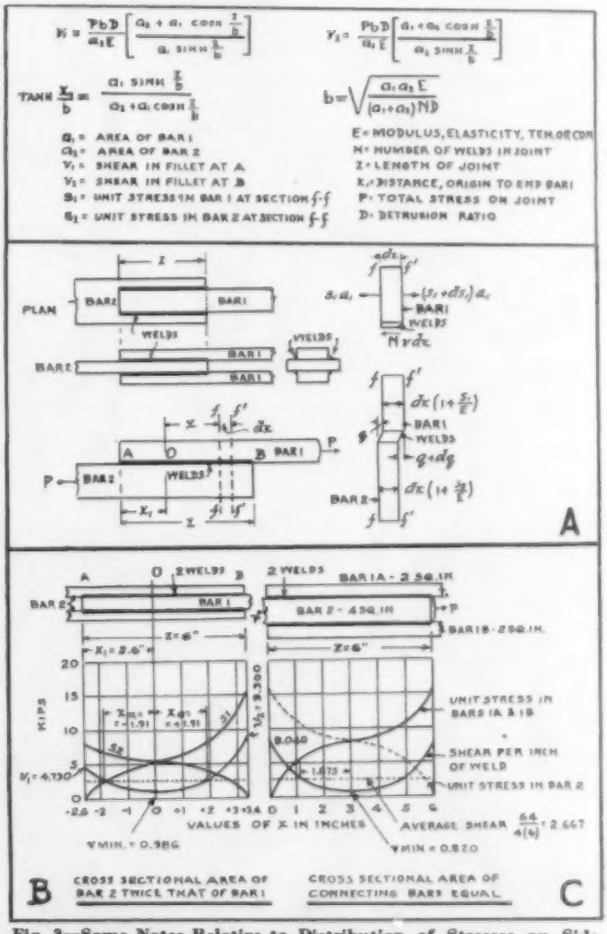


Fig. 3—Some Notes Relative to Distribution of Stresses on Side Fillet Welds as Determined by Mr. Henry W. Troelsch, in November 1932 A. S. C. E. Proceedings

[1] First Report of the British Steel Structures Research Committee.
[2] Journal of the American Welding Society, Sept. and Dec. 1930.
[3] Proceedings of A. S. C. E., Nov. 1932, Mar. 1933.
[4] Proceedings of A. S. C. E., Nov. 1932.

Deformations Applied to Stress Analysis in Side Fillets

Mr. Henry W. Troelsch in November 1932 A. S. C. E. Proceedings and Messrs. Weiskopf and Male in September and December 1930 issues of JOURNAL OF THE AMERICAN WELDING SOCIETY present equations for the distribution of shearing stresses on side fillets, the derivation of which is based on deformations of fillets, and of main and splice plates. The maximum values of shear are at the ends of the fillet, for which Mr. Troelsch, Fig. 3*A* gives the following equations:

$$v_1 = \frac{PdD}{A_2E}\left[\frac{A_2 + A_1 \cosh \frac{Z}{b}}{A_1 \sinh \frac{Z}{b}}\right]$$

$$v_2 = \frac{PbD}{A_1E}\left[\frac{A_1 + A_2 \cosh \frac{Z}{b}}{A_2 \sinh \frac{Z}{b}}\right]$$

To locate the origin, O, find X_1 from

$$\tanh \frac{X_1}{b} = \frac{A_1 \sinh \frac{Z}{b}}{A_2 + A_1 \cosh \frac{Z}{b}}$$

$$b = \sqrt{\frac{A_1A_2E}{(A_1 + A_2)ND}}$$

A_1 = cross-sectional area of bar 1.
A_2 = cross-sectional area of bar 2.
s_1 = unit stress in bar 1 at any section f–f.
s_2 = unit stress in bar 2 at section f–f.
E = modulus of elasticity in tension and compression.
N = number of welds in the joint.
Z = length of the joint.
X_1 = distance of origin O from spliced end of bar 1.
P = total stress (taken as tension) on the joint.
D = detrusion ratio.
v_1 = shear at A; v_2 = shear at B.

Figures 3*B* and 3*C* show fillet stresses in two joints wherein the average shear on each is $P/NZ = 64{,}000/4(6) = 2667$ lb./lin. in.; but the maximum shears, determined by above formulas, are 9300 and 8040 lb./lin. in., or 3.5 and 3.0 times the average shears respectively. If the fillets are $^3/_8$ in. the throat is stressed to a maximum intensity of 9300/0.266 = 34,900 lb./sq. in. or about nine-tenths the ultimate strength. To preserve a proper safety factor the fillet must needs be of 1-in. size. In the derivation of the formulas, it is assumed that the welds, and the bars, deform according to Hooke's law. The formulas are truly applicable to such cases only.

Structural Details for Buildings

Typical connections of beams to beams illustrated in Fig. 4 require no milling of beam ends, except perhaps at the right end of that at *B* where two webs are welded together directly. In general, beams are ordered with the usual mill tolerances as shown at left end of *A*.

In designing bracket angle supports as in *D*, provision must be made for the shear, and for bending in the outstanding leg near the angle fillet, or rather in the vertical leg at the base of angle fillet because the moment is really a maximum there. An interesting but simple study may be made of this by equating the slope of outstanding leg to that of the supported beam.

As a matter of fact, if the angle's outstanding leg and the beam's bottom flange be welded sufficiently as in *C*, the state of stress in the outstanding leg is materially altered because it becomes essentially a part of the beam but bending remains in the vertical leg.

Figure 5 illustrates column splices with intervening bearing plate at *D* between upper and lower column sections of different sizes, also with direct bearing at *F* for column of similar sizes. Attention is called to the arrangement in upper sketch at *H* for simplifying field welding of column splice plates on the rear side of a column located against a masonry wall of an existing building. By using, on the rear flange, a splice plate wider than the flange, the field welding is easily accomplished from the front.

Figure 6 depicts connection of beams to columns for all-welded, as well as for shop-riveted, field-welded buildings, most of which are typical of designs suitable for carrying vertical loads and bending moments. For

Table 2—Data for Welding Steel Building Frames

	Univ.† of California,	Providence Court House,	Boston City Hospital,		Boston Edison,	Dallas P. & L. Company,		Dallas Gas Company,		Dupont Company,
	Field	Field	Shop	Field	Field	Shop	Field	Shop	Field	Field
1. Electrode melted and wasted, lb.	4800	1800	....	1120	2600	7100	4650	6000	5000	3220
2. Current used, kw.-hr.	10,970	3810	...	4150	6120	...	9460	12,200	9990	8395
3. Total steel in buildings, tons	801	811	492	492	1314	1215	1170	700	1000	1576
4. Welders' time, man-hrs.	1827	831	...	557	1206	3140	1768	2000	1640	1411
5. Total length of $^3/_8$-in. fillets, lin. in.	109,572	...	...	...	51,921	97,500	56,415	13,200	51,600	65,400
6. Total length of other fillets, lin. in.	....	....	...	...	8593	25,400	17,842	49,800	28,200	...
7. Total length of all fillets, lin. in.	109,572	54,864	37,138	25,509	60,514	122,900	74,257	63,000	79,800	65,400
8. Fillets per ton of steel in building, lin. in.	136.9	67.6	75.5	51.9	46	101.2	63.5	90	79.8	41.5
9. Welders' time per ton of steel in building, man-hrs.	2.28	1.02	...	1.13	0.917	2.58	1.51	2.86	1.64	0.895
10. Current per ton of steel in building, kw.-hr.	13.71	4.7	...	8.43	4.66	...	8.09	17.4	9.99	5.33
11. Electrode melted and wasted per ton of steel in bldg., lb.	5.99	2.22	...	2.27	1.98	5.84	3.93	8.57	5.0	2.04
12. Welding machine, months	6.92	4.7	...	3	7.5	...	9.1	...	9.3	8.0
13. Steel per welding machine, mos. tons	116	172.5	...	164	175	...	128.6	...	107.5	197
14. Number of welding machines	10	2	...	3	4	...	5	...	5	4
15. Number of stories above basement	8	8*	...	9	14	...	19	...	13	14

* In tower, 17.
† Field connections for all lateral, including seismic forces, arc-welded. Direct loads carried on shop-riveted connections.

example at *E* the "wind" brackets consist of upper and lower tees cut from I-beams as commonly used in similar riveted construction. The vertical loads in this case are carried by the lower tee, the outstanding stem of which is strengthened by two 6-in. by $^3/_4$-in. plate stiffeners. At *F*, two connecting plates are used at the top flange instead of a tee. This sketch also shows plate stiffeners under the lower tee at *C*. In top flange of sketch *J* a slot weld is utilized to increase the length of the weld. Attention is called to the existence of a patent claim on the angle seat supporting the beam between the column flanges at *D*.

Although nearly all building connections shown in Figs. 4, 5 and 6 require erection bolts, it is of interest to state that two patented details, utilizing welded interlocking devices in place of bolts, are available for erection purposes, and are so arranged that holes in beams and columns are largely if not entirely avoided.

Estimating Welding for Multi-Story Buildings

Generally, preliminary estimating is guessing more or

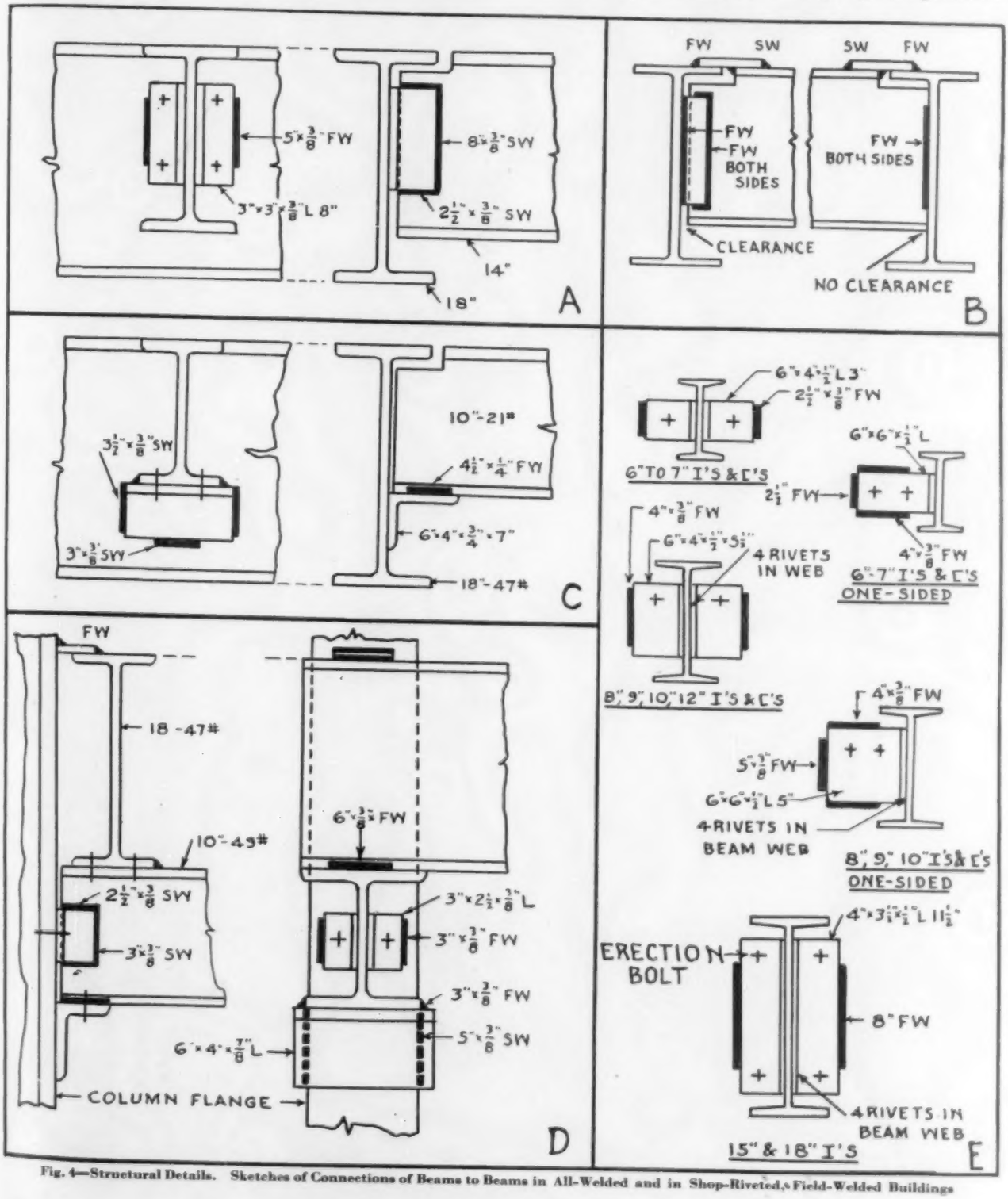


Fig. 4—Structural Details. Sketches of Connections of Beams to Beams in All-Welded and in Shop-Riveted, Field-Welded Buildings

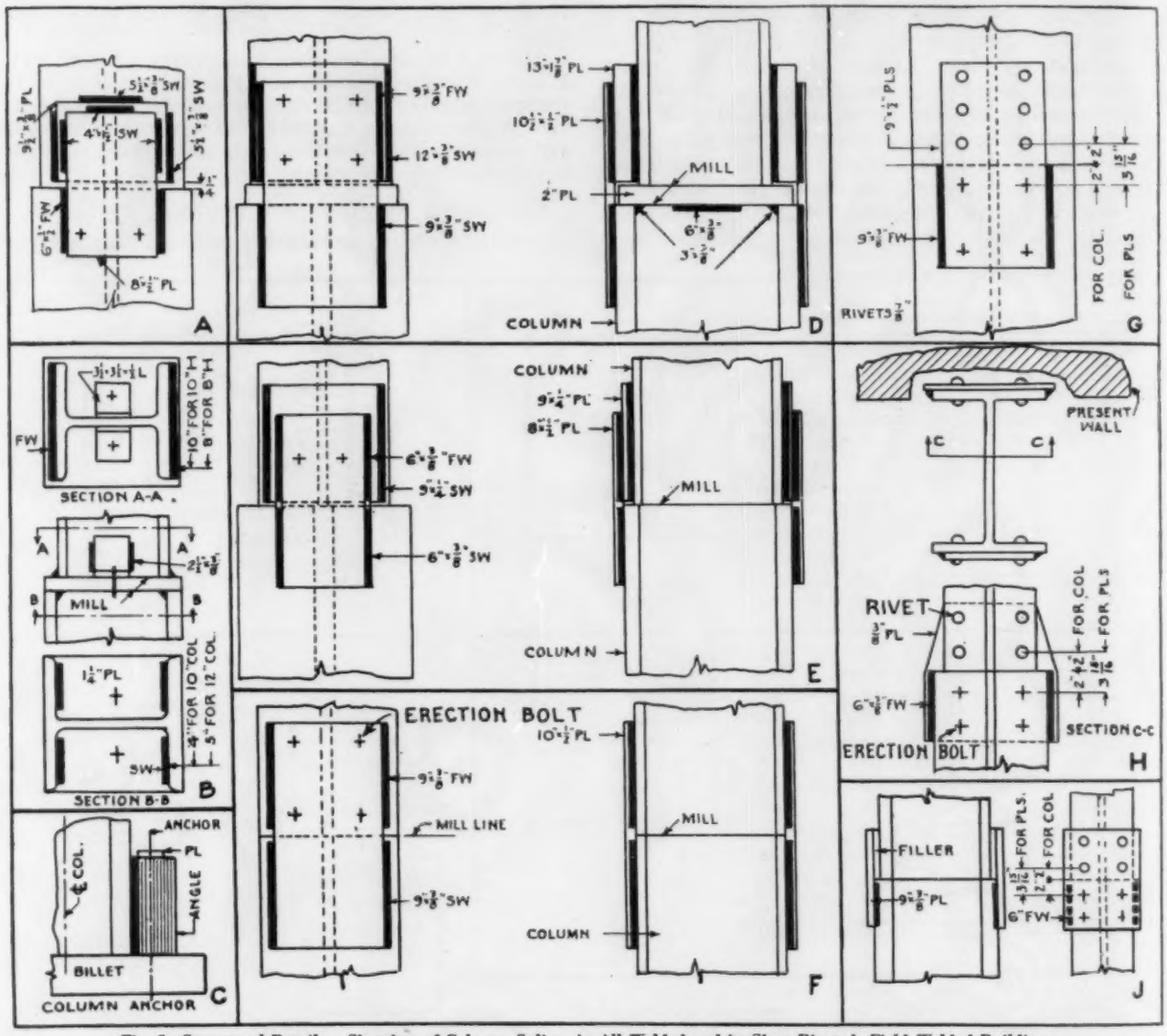


Fig. 5—Structural Details. Sketches of Column Splices in All-Welded and in Shop-Riveted, Field-Welded Buildings

less systematically, because quantities and price units for a proposed building vary from those determined from existing structures. This applies to multi-story welded buildings, as much as to those of other materials, on account of variations in loadings, size and shape of the buildings, arrangement of steel, connections of prime and of secondary members.

Notwithstanding these variables, the following may be of assistance as illustrative of a preliminary estimate for field welding a multi-story steel frame of 2500 tons of steel similar to the Pediatric building of the Boston City Hospital for which some data are shown in Table 2. In the preparation of this table, the welding-machine-months were computed by dividing the "welders' time, man-hours" by 176 for those buildings where no serious delays occurred in erection or welding. The 176 is the number of working hours in a month of four weeks at 8 hrs. per day for $5^1/_2$ days per week. But where delays occurred, the number of machine-months was determined from the total time the machines were at the building site, whether busy or not.

The preliminary estimate for field welding a 2500-ton steel frame follows:

1. Electrode melted and wasted, 2500 × 2.27 = 5675 lb.
2. Welders' total time, 2500 × 1.13 = 2825 man-hrs.
3. Total length of fillets, 2500 × 51.9 = 129,750 lin.-in.
4. Electric current required, 2500 × 8.43 = 21,075 kw.-hr.
5. Number of welding machine-months required to field-weld 2500 tons, 2500/164 = 15.3
6. Number of welding machines required to field-weld in 4 months, 15.3/4 = 4
7. Or number of welding machines required to field-weld in 3 months, 15.3/3 = 5

Splicing Beams for Bending Moment

The AMERICAN WELDING SOCIETY received recently a request for details and incidental computations for splicing two 14-in. 42-lb. Carnegie beams having an included angle of 135 deg. Although it may not be the

function of the Society to serve directly as consultant, several reasons made it advisable in this case to answer the inquiry quite fully. The following is the answer in slightly expanded form:

Case 1. Fig. 7A.—The web is spliced by two vertical plates; each flange by a single Vee butt-weld. Assuming the flanges, exclusive of the portions coincident with the upper and lower extremities of the web, to be fully spliced by the butt-welds the thickness of the web splice plates are determined by the greater of the following two values:

(*a*) By the requirement that the combined moments of inertia of the web splices must equal that of the full web depth, hence,

Thickness, t, for each web splice plate $= bh^3/2d^3$
$= 0.333(14.25)^3/2(11)^3 = 0.363$; say, $^3/_8$ in.

(*b*) Or the thickness of each web splice plate may be determined rather by the dimension of the leg of its fillet as fixed in turn by the stress on its throat (plans X–X, Fig. 7*E*)). The full web depth can transmit a bending moment of $Sbh^2/6$. Equating this with the moments borne by the two fillets on plans X–X, namely, $2vt'd^2/6$, solving for t' and remembering that $t = t'/0.707$,
$t = Sbh^2/1.414vd^2 = 16{,}000(0.333)(14.25)^2/1.414(11{,}300)$
$(11)^2 = {}^9/_{16}$ in.

Where $S = 16{,}000$ lb./sq. in., the allowable unit stress in outermost fiber of the web; and $v = 11{,}300$ lb./sq. in., the allowable unit shear in outermost fiber of the fillet sections on planes X–X.

Finally therefore, since each fillet must be $^9/_{16}$ in., the web splice plates will each be $^9/_{16}$ in.

Another method of arriving at the above value of t is as follows: from Fig. 7*E*, $vt' = tf$; therefore $t' = tf/v$, where f is the intensity of the direct stress in the beam web at top of web splice plates. But since $f = Sd/h$, and $t = bh^2/2d^2$, we have $t' = Sbh^2/2vd^2$, or introducing $t = t'/0.707$; $t = Sbh^2/1.414vd^2$ as before.

Case 2. Fig. 7B. For Positive Moments Only.—The web is spliced by two vertical plates; each flange by two splice plates *inside* of each flange. This arrangement is suitable to resist positive bending moment; that is, one producing compression in upper and tension in lower flange. It is not recommended for negative moments (tension in upper and compression in lower flange), on account of the high concentration of stresses on flange fillets at or near junction of the two beams due to bends in the flange splice plates as at Fig. 7*F*.

(*a*) Assuming the full web depth ($h = 14.25$ in.) to be spliced by two side vertical plates ($d = 10$ in.),

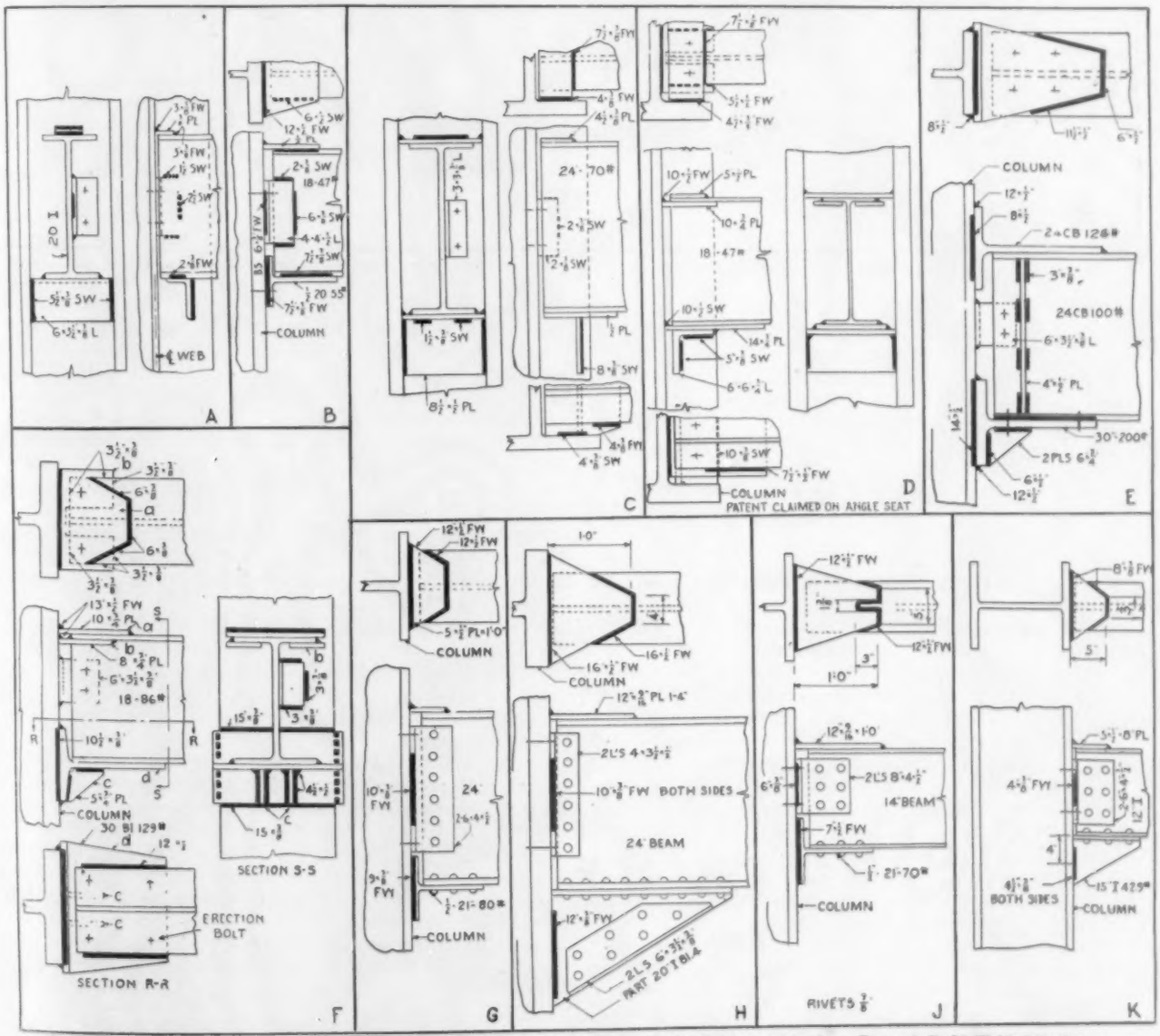


Fig. 6—Structural Details. Sketches of Connections of Beams to Columns in All-Welded and in Shop-Riveted, Field-Welded Buildings

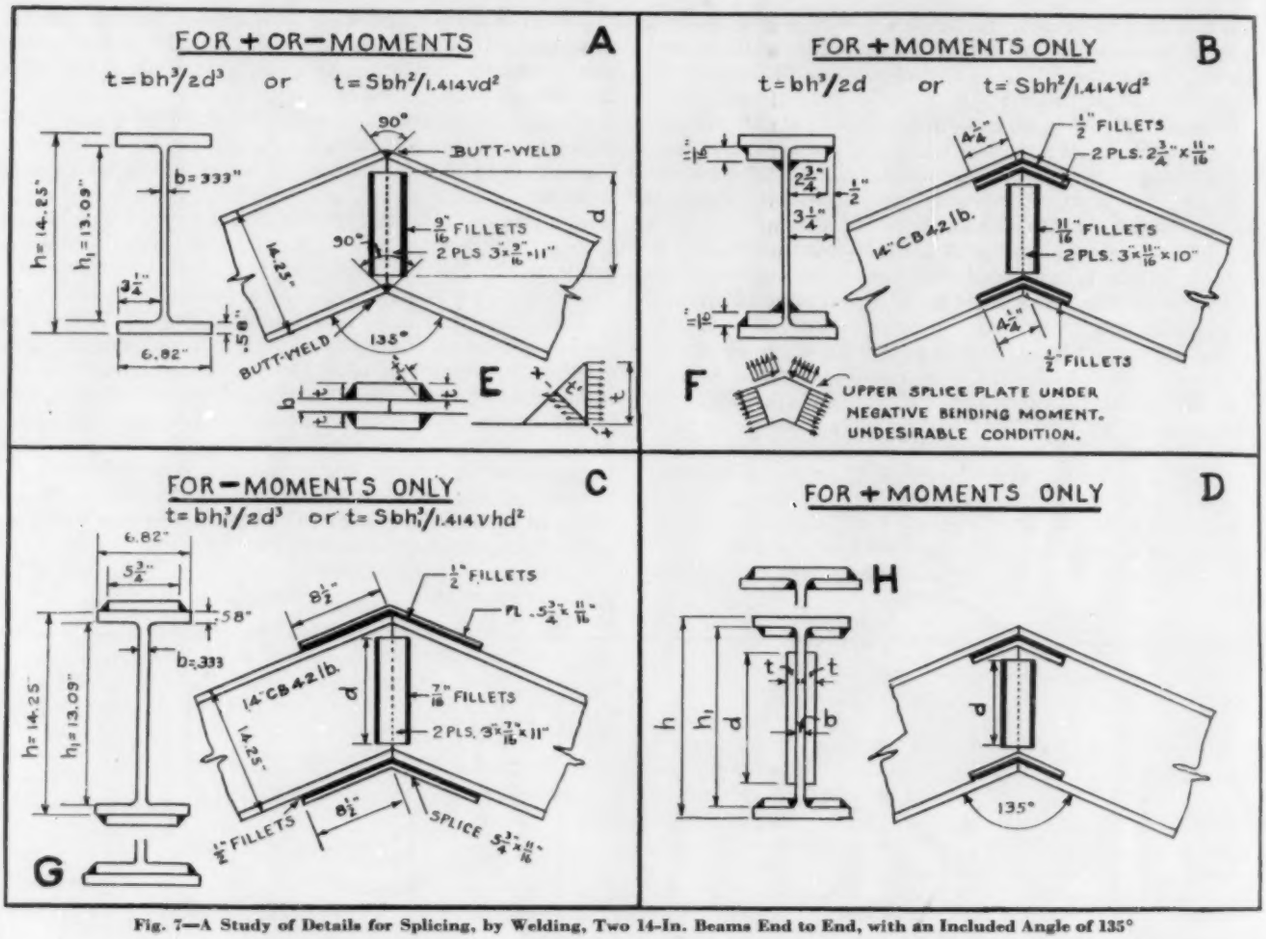


Fig. 7—A Study of Details for Splicing, by Welding, Two 14-In. Beams End to End, with an Included Angle of 135°

t for each web splice plate = $bh^3/2d^3$ = $0.333(14.25)^3/2(10)^3$ = 0.49, say, $^1/_2$ in.

It is noted that the thickness, t = $^1/_2$ in., in this case is greater than $^3/_8$ in. of Case 1, because the depth of web splice plates here is only 10 in. instead of 11 in.; the decreased depth being due to presence of flange splice plates with their fillets.

(*b*) Or based on the dimension of the web fillets,

$t = Sbh^2/1.414\ vd^2 = 16{,}000(0.333)(14.25)^2/1.414(11{,}300)(10)^2$

= 0.68 in., say, $^{11}/_{16}$ in.

In this case, the web splice plates and their fillets are each $^{11}/_{16}$ in.

The flanges are spliced as follows: since the full depth of the web is spliced by the web splice plates, one-half the net area to be spliced in each flange is 0.58(6.82 − 0.33)/2 = 1.88 sq. in., which divided by the width of the flange splice, 2.75 in., gives thickness of each flange splice plate as 0.69, say, $^{11}/_{16}$ in. The only remaining detail to be computed is the length of each fillet (assumed $^1/_2$ in.), connecting the flange splice plates to the main beam. With $^1/_2$-in. fillets, and an allowable unit shearing stress of 11,300 lb./sq. in. on the throat, the permissible unit stress on the fillet is 4000 lb./lin. in. The number of linear inches required for each flange splice plate = 1.88(16,000)/4000 = 7.5 in., or 3.8 in. for each line, say, 4.25 in. to allow for crater, as in Fig. 7*B*.

This same case may be solved on the assumption that the flange plates splice the entire flange area including that portion of the beam's web which lies in the flange and that the web splice plates carry the moment borne by the remainder of the web, that is, between flanges. Were this done, the flange plates would be thicker and the web plates thinner than above.

Case 3. Fig. 7C. For Negative Moments Only.—The web is spliced by two vertical side plates; each flange by one splice plate on the outside. This arrangement, suitable for resisting negative moments, is not recommended for withstanding positive moments because of high concentration of stresses on the flange plate fillets near the bends in the plates.

In this case it is assumed that the entire width of each flange is spliced by the flange plate and that the side web plates carry the moment only of that portion of the web between the flanges:

$t = bh^3_1/2d^3 = 0.333(13.09)^3/2(11)^3 = 0.28$, say, $^3/_8$ in. Or, based on the size of the fillet, $t = Sbh^3_1/1.414\ vhd^2 = 16{,}000(0.333)(13.09)^2/1.414(11.300)14.25(11)^2 = 0.44$, say, $^7/_{16}$ in.

Therefore, as the fillet thickness is $^7/_{16}$ in., each web splice plate will be $^7/_{16}$ in.

The gross area of each flange being 6.82(0.58) = 3.94 sq. in., the required thickness of each flange splice plate (width 5.75 in.) is 3.94/5.75 = 0.69, say, $^{11}/_{16}$ in. And the length of each $^1/_2$-in. fillet of each side of the splice 6.82(0.58)16,000/2(4000) = 7.9 in., say, $8^1/_2$ in., to allow for crater.

If for any reason it be desired that all welding on the flanges be downward, the lower flange plate should be made wider than the beam flange by 1 in. to allow for the two $^1/_2$-in. fillets, Fig. 7*G*, in which case the lower flange splice plate thickness will be, say, 6.82(0.58)/8.0 = 0.49, say, $^1/_2$ in.

Case 4. Fig. 7D. For Positive Moments Only.—This

solution is so similar to Case 2 that details are omitted here. The flange plates will be narrower and thicker than in Case 2 and their inner edges should be beveled to facilitate welding. Fig. 7*H* depicts an alternate design with wider and thinner flange splice plates than in Fig. 7*D*. It is also apparent that an arrangement similar to Fig. 7*H* is applicable to each flange of Fig. 7*B*.

Applicability of Cases 1, 2, 3, 4.—Case 1, wherein the flanges are butt welded, if made by a capable welder using heavy coated or covered electrodes or equivalent, is suitable to resist positive or negative bending moments with an efficiency of 100 per cent; with bare electrodes of structural steel grade, approximately 85 per cent efficiency. Cases 2 and 4 are designed to withstand positive moments; Case 3 for negative moments. With proper welding the efficiency of each of these joints should be 100 per cent.

Bare *vs.* Covered Electrodes

Either bare, coated or covered electrodes suitable for welding the mild steel of bridges or building frames, are satisfactory for welding wrought iron bridges. In many cases, bare wire is perfectly suitable. But coated or covered wires, other things being equal, produce greater strength and ductility. And although the cost of bare wire alone is less than that of coated or covered, the increased speed of welding with either of the two last named may result in lower final cost.

A requirement, desirable to include in specifications for structures where coated or covered wires are to be used and are likely to be bent in order to reach places in welding difficult of access, is that the wire shall withstand ordinary handling, including a 90-deg. bend, without breaking off the coating or covering.

Table 3—Tension and Free-Bend Ductility Qualification Tests for Three Welders on Position Pipe Joints of Mercury-Steam-Electric Power Station at Schenectady, Using Coated Electrodes

Welding Position	Welder's Number	Ultimate Strength, Lb./Sq. In.	Ductility Free-Bend, Per Cent
Flat	1	65,200	35.5
Flat	2	63,350	36
Flat	3	64,400	30
	Average	64,320	33.8
Vertical	1	65,000	35.5
Vertical	2	55,900	36
Vertical	3	71,900	26
	Average	64,200	32.5
Overhead	1	65,300	34.2
Overhead	2	62,400	38.3
Overhead	3	64,450	35.5
	Average	64,050	36.0

Table 4—Limitations of Certain Chemical Ingredients and Impurities of Iron and Steel Bare Electrodes for Arc Welding and of Iron and Steel Plain or Copper-Coated Welding Rods for Gas Welding, A. W. S. May 1, 1921

	For Electrodes Grade E—No. 1A and for Gas-Welding Rods G—No. 1A	Electrodes, Grade E—No. 1B
Carbon	Not over 0.06%	0.13–0.18%
Manganese	Not over 0.15%	0.40–0.60%
Phosphorus	Not over 0.04%	Not over 0.04%
Sulphur	Not over 0.04%	Not over 0.04%
Silicon	Not over 0.08%	Not over 0.06%

Remarkably uniform ductility and strength are revealed in Table 3, giving free-bend ductility percentages and ultimate tensile strengths of A. S. M. E. reduced section specimens taken from welds made in 14-in. diam., $^1/_2$-in. wall thickness, seamless steel tubing in qualification of three welders making position welds on pipe joints in the General Electric Company's mercury-steam-electric power plant at Schenectady, using that company's covered electrode. The yield point varied from 40,000 to 50,000 lb./sq. in. on reduced-section tension pieces.

In the early requirements of the American Welding Society's welding wire specifications, one of the principal criteria was limitation of chemical ingredients and impurities, Table 4, as shown herewith; but it is probable that when the new specifications are issued these chemical elements will not be mentioned; instead, the basic requirement will probably be the strength of welded joints resulting from the use of the filler metals.

Resistance Welding of Structural Steel for Buildings

Resistance welding is utilized in steel building construction for shop fabrication of (*a*) bar joists for use as floor joists and roof purlins; and (*b*) of small trusses suitable for either joists or purlins on somewhat longer spans. Parts of stairs are also welded in this manner.

(*a*) In general, bar joists are shallow trusses, spaced from 1 ft. to $2^1/_2$ ft. on centers, on spans up to 32 ft., ordinarily of Warren truss type with round continuous rods bent to form web members welded at the truss joints to upper and lower chords of rolled steel shapes. The carrying capacity depends, not only on the strengths of the individual web and chord members and on proper lateral bracing of the entire truss, but also on the strength (usually shearing strength) of the welds.

Figure 8 presents results of a load-deflection test on a Truscon resistance welded bar joist. During the test, two trusses were placed parallel, braced together and loaded uniformly over the entire span, deflections being taken at various joints as the loads increased. The deflections recorded in Fig. 8 are those at the center of the span. At 4760 lb., the rated safe capacity for each joist, the central deflection was 0.56 in., as compared with 0.69 in., which is the usually accepted maximum deflection of 1/360 of the 20-ft. 8-in. clear span. Deflections were measured till the total load on each truss

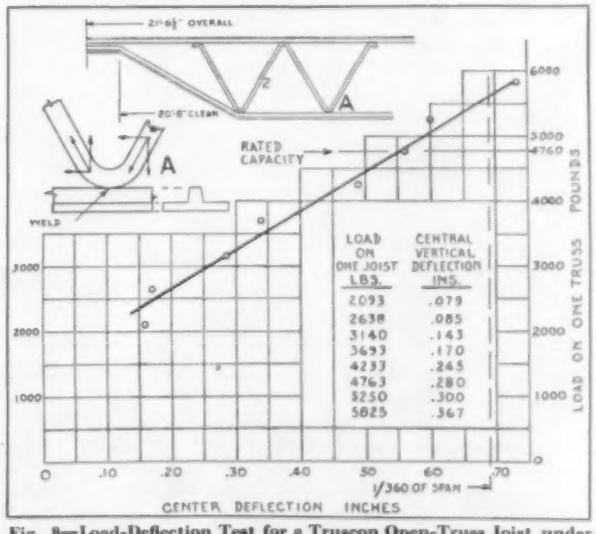


Fig. 8—Load-Deflection Test for a Truscon Open-Truss Joist under Uniform Loads over Entire Span

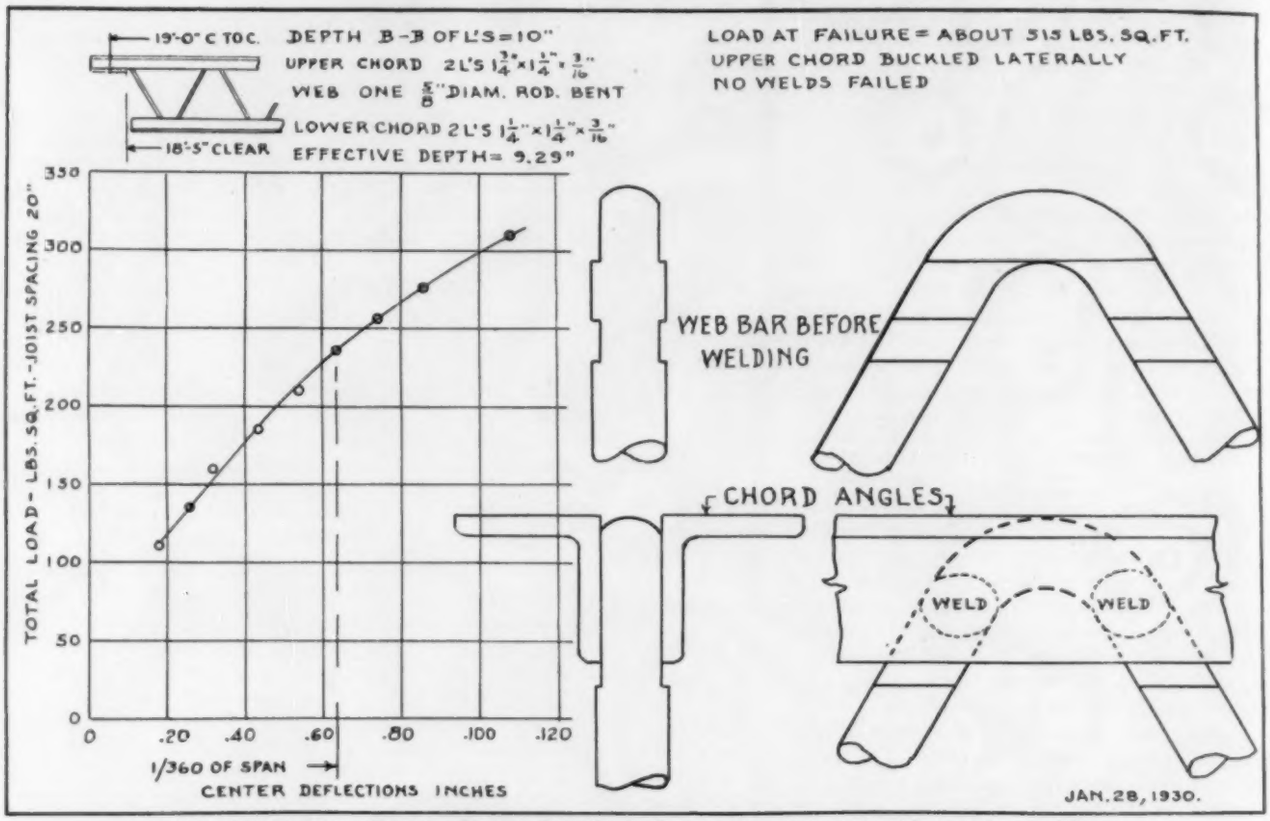


Fig. 9—Load-Deflection Test for a Macmar Joist (Junior Truss) under a Concentrated Load at Center of Span

was 5825 lb., after which the loading was continued till ultimate failure occurred in the upper chord at center under a uniformly distributed load of 11,790 lb. per truss. No welds failed. Test was conducted by Pittsburgh Testing Laboratory.

The welds in the above truss are subjected to horizontal shearing forces, the maximum value of which occurs in the unloaded chord (usually the lower) and equals twice the horizontal component of the maximum stress in any web diagonal as at *A*, Fig. 8, except at the end lower chord joint where it equals practically the maximum horizontal component in the end diagonal 2.

Another type of bar joist (Macmar), Fig. 9, consists of a continuous-bent-rod web system, resistance welded between two angles in each chord. In order to limit the size of the welds, the web member is flattened at each chord joint so that the current flow is limited to two lugs, each about $^1/_2$ in. long, Fig. 9. The truss members are assembled in a horizontal plane, then current and pressure are applied to the chord angles to weld the web rods between these angles. Figure 9 records, for a Macmar joist, a load-deflection test conducted by Professor H. C. Berry, Jan. 21, 1930.

(*b*) The small trusses mentioned above, intended for slightly longer spans than those of bar joists, are used in roofs of hangars and in garage roofs and floors. The Truscon type for spans up to 56 ft. consist of Pratt trusses made of channel upper and lower chords, connected with verticals and diagonals, each of two angles welded by resistance or arc to the channel flanges.

Although nearly all connections of web and chord members of bar joists are made by some form of electric pressure welding and are dependent for their strength on resistance to shearing of the welding, I find very little accurate data concerning the strength of resistance welds in shear. The satisfactory service which bar joists of various types are giving and the absence of failures in this form of construction, indicate that they are well made and of ample strength. But perhaps the welding is too strong. Perhaps too much welding is being done on them; if so, it would seem possible by securing more accurate strength data to reduce the amount of welding. Certainly as the use of resistance welding is extended into larger units, the necessity of adequate shear tests will become more apparent. But possibly manufacturers think that "sufficient unto the day is the evil thereof." However, engineers desire the data.

(*To be continued in June issue Journal A. W. S.*)

Reprints of the complete paper by Prof. McKibben are available at Society Headquarters, at 35 cents per copy.

A New Type of Welding Course

By L. F. JACKSON

†Presented at Business Session, Annual Meeting, American Welding Society, April 27, 1933, by L. F. Jackson, Chairman, Boston Section.

THE common run of welding courses fall into one of two classifications; highly technical courses in metallography in the colleges and universities and the practical courses given in trade schools.

Both of these types leave a great deal to be desired from the standpoint of the average engineer and operator. The engineer lacks sufficient knowledge of the actual welding operation to apply welding intelligently and the operator has insufficient technical knowledge to appreciate the end toward which the designer is working.

With these ideas in mind, Mr. H. R. Bullock of the Mechanical Engineering Department of the Massachusetts Institute of Technology approached the Executive Committee of the Boston Section of the A. W. S. and suggested that some form of semitechnical, semipractical lecture course be given under the auspices of the Society. Mr. Bullock explained to the Committee that in his opinion such a course would satisfy the requirements of the average engineer and operator more fully than any other type of course. As you will see later, this expectation was justified. The Executive Committee voted unanimously to give such a course their whole-hearted support and that they went through is attested by the enclosed letter of thanks from Mr. Bullock.

A great deal of credit is due to the Massachusetts State Department of Education and particularly to Mr. John F. Wostrel of that department in making the necessary arrangements for giving this course, inasmuch as there was no concrete information available concerning the interest which would be shown. It was originally thought that the class would probably consist of 30 to 40 men but this estimate turned out to be far too low and the actual registration proved to be 104.

Because of its immediate popularity in Boston, the University Extension people decided to conduct the same course in Worcester. Although the Worcester section did not get started until very late in the season, an enrollment of 30 was made.

Topical outline of the course was as follows:

I. (*a*) Fusion welds; plastic welds
   (*b*) Joint efficiency
   (*c*) Forge welding
   (*d*) Thermit welding
   (*e*) Resistance welding
      1. Upset butt and flash welds
      2. Spot and shot welding
      3. Seam welding

II. Fusion welding and cutting by the oxyacetylene process
   (*a*) Chemistry of the welding flame
   (*b*) Chemistry of the cutting flame
   (*c*) Apparatus used
   (*d*) Steel welding; forward and backward
   (*e*) Cast-iron welding—cast-iron filler rod, bronze, preheating and annealing
   (*f*) Aluminum welding
      1. Sheet
      2. Castings
      3. Flux, puddling rod, flame adjustment
   (*g*) Welding brass and bronze
      1. Flame adjustment
      2. Procedure
      3. Filler rods
   (*h*) Cutting steel and cast iron
      1. Proper procedure
      2. Gas pressures
      3. Effect of varying pressures and impurities in gas on smoothness of kerf and cost of cutting
   (*i*) Hard surfacing
   (*j*) Automatic welding and cutting

III. Arc welding
   (*a*) Mechanics of the arc
   (*b*) Apparatus used
   (*c*) Welding steel
      1. Rigid set-up
      2. Non-rigid set-up
      3. Horizontal, vertical and overhead welding
   (*d*) Manganese and alloy steel electrodes
   (*e*) Procedure used with cast iron and aluminum
   (*f*) Automatic welding
      1. Metallic arc
      2. Carbon arc
   (*g*) Atomic arc, shielded arc and fluxed electrodes

IV. Metallography of welding
   (*a*) Equilibrium diagrams and cooling curves
   (*b*) Micro structure

V. Metallography of welding
   (*a*) The iron carbon diagram and its application to welding
   (*b*) Characteristic micro structure
   (*c*) Desirable and undesirable characteristics

VI. Design and strength of joints
   (*a*) General types
      1. Butt
      2. Lap
      3. Strap
      4. Fillet
   (*b*) Tensile strengths
   (*c*) Elastic limits
   (*d*) Fatigue resistance
   (*e*) General faults in design
   (*f*) Heat treatment and stress relief
   (*g*) Procedure control
   (*h*) Qualification of operators

VII. Industrial welding
   (*a*) Pipe Welding
   (*b*) Pressure Vessels
   (*c*) Structural Steel
   (*d*) Airplane
   (*e*) Machine frame construction
   (*f*) Ship building

VIII. Application of theory to practical problems
   (*a*) Analysis of typical shop and field problems
   (*b*) Lines of attack and development
   (*c*) Solution

It was given as a series of 8 two-hour lectures and proved to fill the bill admirably, the classes being about equally divided between engineers and operators.

Occupations of men registering in the Boston class were as follows:

Draftsman	10	Foreman	8
Welder	17	Insurance inspector	3

Not stated	5	Manager	2
Welding supervisor	3	Teacher	1
Laboratory worker	1	Plumbing heating contractor	2
Welding engineer	11	Auto repair	2
Metal worker	2	Unemployed	1
Bridge designer	2	Salesman	2
Mechanic	1	Boiler layer-out	1
Plant superintendent	4	Machinist	1
Mechanical engineer	8	Oil burner	1
Student	4	Electrician	1
Architectural engineer	1	Office	1
Loftsman	1	Builder	1
Civil engineer	4	Electrical engineer	2
Chauffeur	1	Marine surveyor	1

It is suggested by the Boston Section that other sections of the A. W. S. interest themselves in promoting such a course since it has a great deal of interest in New England and has materially assisted class members to properly apply welding in their work.

Interest in the course was very high, men being drawn from all parts of New England; one man made a trip from Springfield to Boston and back each week.

At the request of the class, an advanced course in design and metallography followed with an enrollment of 26.

The Massachusetts Department of Education plans to repeat the courses in both Boston and Worcester next fall. By starting them earlier in the season, it is believed that a greater enrollment will be obtained.

An Arc-Welded Highway Bridge Design

By IRA D. S. KELLY

†Mr. Kelly is Bridge Designer, Kansas State Highway Commission, Topeka, Kansas.

ON THE opposite page are shown the important details of an arc-welded through truss steel highway bridge designed for a span of 140 ft. 0 in. c. c. of bearings and a roadway width of 24 ft. 0 in. top-to-top of curbs for an H-15 loading with provision for a 100% increase in live load in accordance with (1) the "Standard Specifications for Highway Bridges and Incidental Structures" by the American Association of State Highway Officials, Edition of 1931, except for the provisions of Specification No. 1, Sec. 10, Par. 3.10.34, Welds, which states that, "Welding of steel shall not be done except to remedy minor defects and then only with the approval of the Engineer," and except for the specification prohibiting lower chord splices at truss joints. Welded connections are designed in accordance with (2) "Specifications for Arc-Welded Connections in Bridges" by Gilbert D. Fish, Consulting Structural Engineer, Westinghouse Electric and Manufacturing Company, using his method of computing welded connection design stresses and his allowable unit stresses on welds as given below in Table 1. Valuable information was secured from (3) "Major Provisions of an Arc-Welding Specification" by Frank P. McKibben, Consulting Engineer, General Electric Company and (4) the "Code for Fusion Welding and Gas Cutting in Building Construction" by the AMERICAN WELDING SOCIETY Committee on Building Codes, Part A, Structural Steel, Edition of 1930.

Table 1—Allowable Unit Stresses on Welds

Type and size	1/2 In. F. W.	3/8 In. F. W.	5/16 In. F. W.	1/4 In. F. W.	3/4 In. S. W.	1 In. S. W.
Critical area, sq. in.	0.3535	0.2651	0.2209	0.1768	0.7500	1.00
Direct stress, lb./lin. in.	5655	4240	3535	2830	12,000	16,000
Shearing stress, lb./lin. in.	3535	2650	2210	1770	7500	10,000

The design was prepared as part of a study of the adaptability of arc welding to bridge design and was compared as to weight and cost with a standard riveted design for the same span and roadway in use by the Kansas Highway Commission. The same type of truss and reinforced concrete floor were used on both designs. A comparison of the weights of these designs is given in Table 2 below.

Table 2—Weight Comparison

	Riveted Design Struct. Steel, Lb.	Welded Design Struct. Steel, Lb.	Saving Lb.	Saving %
Stringers	39,480	36,560	2920	7.4
Floor beams	29,090	27,290	1800	6.4
Trusses	78,030	64,050	13,980	17.9
Wind bracing and hand-rails	26,200	23,220	2980	11.2
Total structural steel	172,800	151,120	21,680	12.5
Floor weight	226,395	226,395	None	None
Total weight of span	399,195	377,515	21,680	5.4

The cost of welding was estimated by a method given in "Arc Welding," Chapter VI, published by the Lincoln Electric Company. Time required to place the various types and sizes of welds was taken from diagrams in "Arc Welding." The per cent of time actually spent in welding was estimated at 80% in the shop and 50% in the field. The cost of labor was estimated at 80¢ per hour in the shop and $1.00 per hour in the field. An allowance of 20% was made for wastage. Welding metal was estimated at 8¢ per lb., current at 13¢ per hour and overhead at $5.00 per month. A profit of 10% was added.

The total length of each type and size of weld required was computed and used with the appropriate unit cost to determine the cost of welding as given in Table 3 below.

The cost of structural steel in place including welding was estimated as follows:

		Per Lb.
Average bid price for structural steel in place including rivets	=	$0.0600
Estimated cost of rivets = 14,310 rivets at 10¢ each / 172,800 lb. str. steel	=	−0.0083
		0.0517
Estimated cost of welding = $779.96 cost of welds / 151,120 lb. str. steel	=	+0.0052
Estimated average bid price for structural steel in place including welding	=	$0.0569

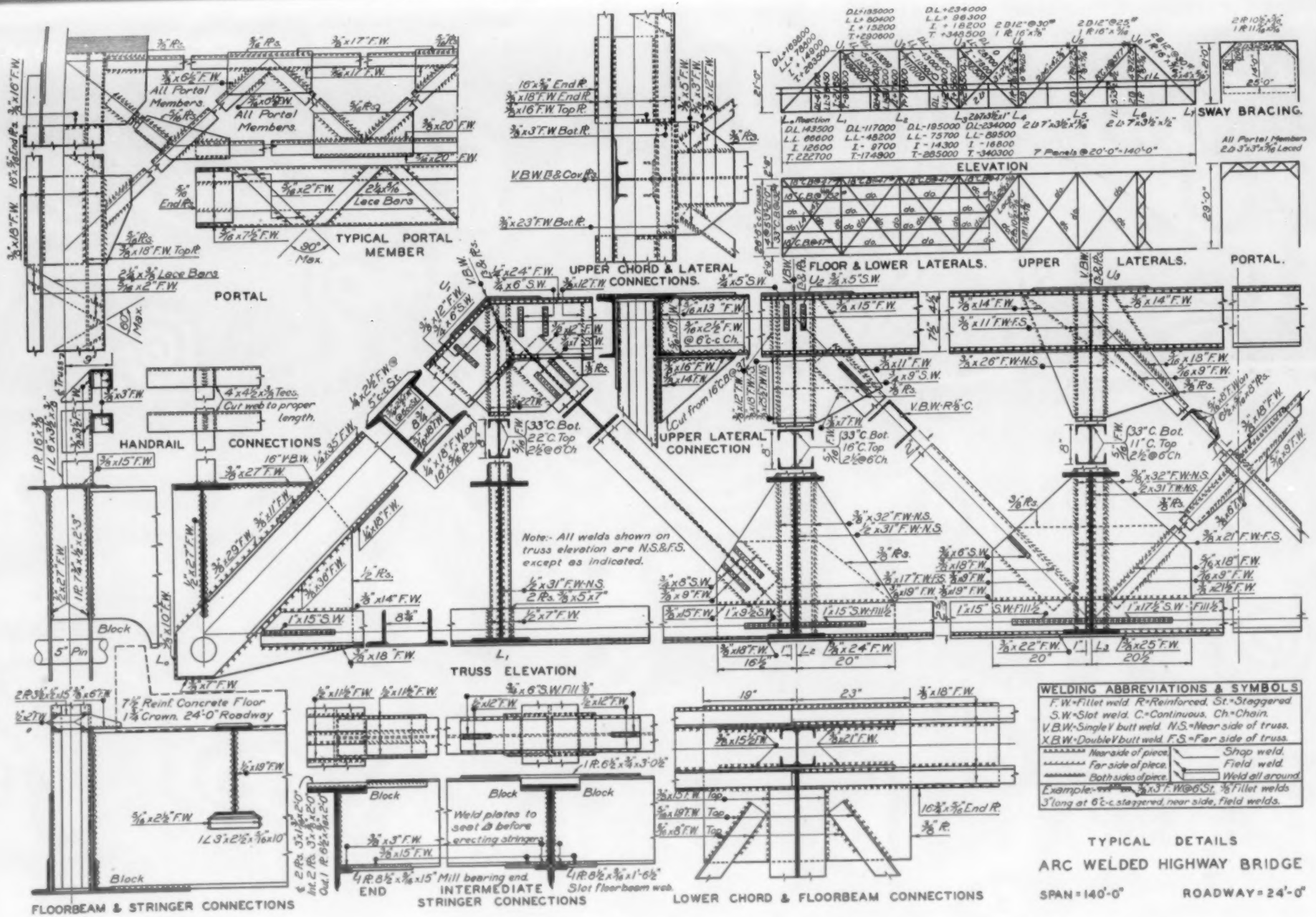

TYPICAL PORTAL MEMBER
PORTAL
HANDRAIL CONNECTIONS
UPPER CHORD & LATERAL CONNECTIONS.
UPPER LATERAL CONNECTION
FLOOR & LOWER LATERALS.
UPPER LATERALS.
PORTAL.
SWAY BRACING.
ELEVATION
TRUSS ELEVATION
Note:- All welds shown on truss elevation are N.S.&F.S. except as indicated.
7½" Reinf. Concrete Floor
1⅞" Crown. 24'-0" Roadway
Block
5" Pin
Weld plates to seat ⌀ before erecting stringer
FLOORBEAM & STRINGER CONNECTIONS
END
INTERMEDIATE STRINGER CONNECTIONS
LOWER CHORD & FLOORBEAM CONNECTIONS
WELDING ABBREVIATIONS & SYMBOLS
F.W.=Fillet weld. R=Reinforced. St.=Staggered
S.W.=Slot weld. C.=Continuous. Ch.=Chain.
V.B.W.=Single V butt weld. N.S.=Near side of truss.
X.B.W.=Double V butt weld. F.S.=Far side of truss.
Near side of piece. Shop weld.
Far side of piece. Field weld.
Both sides of piece. Weld all around
Example:- ⅜"x3" F.W.@6"St. ⅜ Fillet welds 3" long at 6" c.c. staggered, near side, field welds.
TYPICAL DETAILS
ARC WELDED HIGHWAY BRIDGE
SPAN = 140'-0" ROADWAY = 24'-0"

Table 3—Summary of Length

Type and Size		1/2 F. W.		5/16" F. W.		5/16" F. W.		1/4" F. W.		1" S. W.		3/4" S. W.	
Unit Costs, $/Lin. Ft.	Shop Field	$0.162 $0.272		$0.107 $0.184		$0.087 $0.154		$0.068 $0.120		$0.839 $1.465		$0.468 $0.825	
Part of Bridge	Where Placed	Length	Cost	Length	Cost	Length	Cost	Length	Cost	Length	Cost	Length	Cost
Stringers	Shop	38'4"	$ 6.21	30'0"	$ 3.21	30'0"	$ 2.61	....	....	...	....	...	....
	Field	380'0"	103.36	180'0"	33.12	.....	.....	....	....	...	....	30'0"	$24.75
Floorbeams	Shop	....	.....	.....	.....	.....	.....	....	....	...	....	...	....
	Field	95'10"	26.07	54'0"	9.94	.....	.....	....	....	...	....	...	....
Trusses	Shop	36'0"	5.83	467'8"	50.04	1216'10"	105.86	428'2"	$29.12	21'8"	$18.18	11'4"	5.30
	Field	18'8"	5.08	396'6"	72.96	54'8"	8.42	....	....	26'4"	38.57	41'4"	34.10
Lateral bracing and handrails	Shop	....	.....	135'0"	14.45	621'8"	54.09	....	....	...	....	...	....
	Field	....	.....	304'2"	55.97	174'6"	26.87	....	....	...	....	...	....
Totals	Shop	74'4"	12.04	632'8"	67.70	1868'6"	162.56	428'2"	29.12	21'8"	18.18	11'4"	5.30
	Field	494'6"	134.51	934'8"	171.99	229'2"	35.29	....	....	26'4"	38.57	71'4"	58.85
	Shop and field	568'10"	146.55	1567'4"	239.69	2097'8"	197.85	428'2"	29.12	48'0"	56.75	82'8"	64.15

The estimated costs of the riveted and welded designs were computed as given in Table 4 below.

Table 4—Cost Comparison

Riveted Design	Volume or Weight	Unit Cost	Total Cost
Class A concrete–cu. yd.	55.9	$18.00	$ 1,006.20
Reinforcing steel–lb.	10,440	0.045	469.80
Structural steel–lb.	172,800	0.06	10,368.00
	Total cost		11,844.00
Welded design			
Class A concrete–cu. yd.	55.9	$18.00	1,006.20
Reinforcing steel–lb.	10,440	0.045	469.80
Structural steel–lb.	151,120	0.0569	8,598.73
	Total cost		10,074.73
	Saving in cost		1,769.27
	Saving in cost		15.0%

The reader's attention is directed to the following details of the welded design:

Stringers are designed for continuity through the floor beams. Note the use of top splice plates passing over the top flanges of the floor beams at such heights as to provide for a roadway crown of 1 3/4 in. and bottom splice plates passing through the floor-beam webs near the neutral axis. The stringer webs are welded directly to the floor-beam webs to provide for shear. The shelf angles have been assumed not to carry any load other than erection loads.

Floor beams are designed as simply supported beams with an allowance for live load impact of 33 1/3% on intermediate floor beams and 60% on end floor beams. Shear is carried by fillet welds between the floor-beam webs and the truss gusset plates. In order to reduce stresses on these welds due to moment, straps are welded connecting the truss posts and hangers with the floor-beam top flanges, and the floor-beam bottom flanges are welded to the bottom lateral gusset plates. The connection is adequate to develop the entire resisting moment of the intermediate posts or hangers. End floor-beam connections are adequate for future jacking operations under the floor beams.

Truss members are chosen to meet the requirements of radius of gyration, minimum weight, required cross-sectional area, controlling truss dimensions, practical joint assemblies, accessibility of required welds and rolled sections available.

No combination studied was found more economical for end post and upper chord members than two channels connected by a cover plate on top and lace bars on the bottom. Welding of these members is designed in general by replacing the rivets required by specifications with welds of equal strength. Vertical truss members are composed of two channels with legs in, connected by a web plate welded to the channel webs. This combination provides a very economical member as well as adequate strength. The truss diagonal member, U_1-L_2 consists of a single H-section while the remaining diagonals are composed of two angles with legs in. The instanding legs of the U_2-L_3 diagonal angles are continuous butt welded together utilizing the rounded edges of the legs to form a single V. The angles of the third diagonal member are connected by means of tie plates spaced as for the riveted design. Lower chord members consist of two angles with legs out and down using the same size angles throughout but different thicknesses in different panels. This combination provides a landing seat for the floor beam during erection and does not require a reduction in area at the joint as is the case where channels are used and the top outstanding leg is blocked out at the floor beam connection. Bottom lateral diagonals use the same size angles as the riveted design. Top lateral diagonals and portal members consist of two angles laced. Top lateral struts are built up of two flange plates and a web plate welded to form an H-section. A sway brace is provided but not shown which consists of two angles separated by means of blocks corresponding to ring fills used on a riveted design. These blocks are not as wide as the legs of the angles and form a slot along each edge which is welded to connect angles and block and give a weld that will be out of sight. The ends of these braces are welded to the webs of sections cut from an 8 in. C.M. at 19 lb. which in turn are welded to the bottom flanges of the top lateral struts and the inner flanges of the truss intermediate posts. Hand-rails are the same as the riveted design except for connections which are T-sections.

The "cabin" assembly at the L_0 joint eliminates all connection angles and substitutes a diaphragm plate and a cover plate connected by fillet welds. Note that the cover plate of the end post is slotted so as to fit over the gusset plates and allow sufficient welding along each side to transfer its load to the gusset plates. The lower chord angles at this joint are connected to the gusset plates by means of slot welds on the neutral axis of the angles and fillet welds along the edges of the angle. Sufficient fillet weld is used before reaching the slot to relieve the angle of that portion of its load that would have been carried by the metal removed by the slot. Additional fillet welds are used here along the angle legs to insure a greater distribution of stress trans-

and Cost of Welding

5/16" S. W.		3/8" V. B. W.		5/16" V. B. W.		Totals		Shop and Field		Structural Steel, Lb.	Welding per Lb. of Str. Steel Ft./Lb.		Cost of Welding per Lb. of Str. Steel	
$0.169		$0.211		$0.314										
Length	Cost	Length	Cost	Length	Cost	Length	Cost	Length	Cost				Dollars/Lb.	
...	...	....	....	...	...	98'4"	$ 12.03	688'4"	$173.26	36,560	0.0027	0.0188	$0.00033	$0.00474
...	...	....	....	...	...	590'0"	161.23				0.0161		0.00441	
...	...	....	....	...	...	.....	.....	149'10"	36.01	27,290	....	0.0055	.....	0.00132
...	...	....	....	...	...	149'10"	36.01				0.0055		0.00132	
...	...	116'0"	$24.48	...	...	2297'8"	238.81	2893'2"	416.15	64,050	0.0358	0.0451	0.00373	0.00650
...	...	....	....	58'0"	$18.21	595'6"	177.34				0.0093		0.00277	
18'8"	$3.16	....	....	...	...	775'4"	71.70	1254'0"	154.54	23,220	0.0334	0.0541	0.00309	0.00666
...	...	....	....	...	...	478'8"	82.84				0.0207		0.00357	
18'8"	3.16	116'0"	24.48	....	....	3171'4"	322.54	4985'4"	779.96	151,120	0.0210	0.0330	0.00213	0.00516
...	...	....	....	58'0"	18.21	1814'0"	457.42				0.0120		0.00303	
18'8"	3.16	116'0"	24.48	58'0"	18.21	.....	.....	.....	.....	.....	....	....	.....	.....

fer, but at other angle connections the amount of welding on each side of the angle has been balanced about the neutral axis of the angle. An allowance of 1/2 in. has been added to all welds for the crater.

The U_1 joint assembly is designed for maximum accessibility. The gusset plates are connected to the chord and end post by means of fillet welds along their edges and slot welds through the channel webs to the gusset plates. The entire cross sections of upper chord members are single V butt welded together.

The L_2 joint assembly provides for splicing the angles at the joint and makes use of the gusset plates both vertical and horizontal as splice plates. It is thought this assembly provides a practical, economical and accessible connection.

A few observations based on the experience gained from this arc-welded design may be of interest.

It appears practicable to utilize arc welding entirely on initial bridge design and that welded connections can be devised that will provide adequate strength, will be accessible for welding and inspection and will be no more difficult to erect than riveted connections.

There remains no doubt that at present more time is required to prepare a welded design than a riveted design. The time required can be reduced on future designs through greater knowledge and experience and through the use of more convenient welding abbreviations and symbols. The abbreviations and symbols shown are an adaptation of those used by the Kansas City Structural Steel Company but they have the disadvantage of requiring too many notes, lines and arrows around a joint and present a congested appearance on the drawing. It is hoped a system will be devised that will make the symbol used tell the entire story as to type, size, length, location and whether field or shop without resort to notes.

When all the connections of a bridge are arc welded, the bridge becomes one piece of metal. The truss design presented was analyzed for stresses in the members by the usual method which considers all joints to be pin-connected. It is recommended that future arc-welded bridges be analyzed as monolithic elastic structures and that members and connections be designed for combined bending and direct stress. The use of higher allowable unit stresses on the welds then should be allowed.

Welding as used on this design is penalized in three ways as compared to riveting. The method of computation of connection design stresses results in higher stresses than the method used for riveted connections. This method requires connections to be designed for a stress $= M + \frac{M-N}{2}$ in which M = Maximum computed stress in the member. N = Minimum computed stress in the member. This is thought to be a reasonable precaution. The allowable unit stresses are too low for modern welds. Revised allowable unit stresses should be determined from tests of welds made by modern equipment and processes. It appears reasonable to specify definitely in a contract the equipment and welding process that shall be used and the strength and physical properties of the resulting welds in order that advantage may be taken of modern strong and ductile welds. When designing a riveted bridge, it is the custom to increase the allowable unit stresses on rivets by one third when considering stresses due to a 100% increase in live load. Allowable unit stresses on welds used for the design shown have not been increased a corresponding amount. It appears reasonable to increase the allowable unit stresses on welds by one third when designing for a 100% increase in live load.

It was thought best on this design to leave details of erection to be worked out between the engineer, the shop and the contractor. It is believed that the requirements of erection for welding are not beyond the ability of modern ingenuity and equipment.

The estimates prepared show a definite economy in structural steel due to the use of arc welding. This economy results from the use of gross section of tension members, elimination of connection angles, reduction in size of gusset plates, more economical built-up sections, design for continuity and reduction in design stresses due to reduction in dead load. The structural steel required is reduced 12.5%, the total dead load of the bridge is reduced 5.4% and the total cost based on about 1931 prices is reduced by 15.0%. Bridge designers should be alert to these economies. It is interesting to note that 14,310 rivets have been replaced by 4985 ft. 4 in. or 0.94 mile of welding of all types and sizes.

It is realized that many details shown on the drawing and given in the estimates are debatable and that it is unlikely any two designers would arrive at a similar design on the basis of what is known of the application of arc welding to initial bridge design. The design is presented in the hope it may renew an interest in the possibilities and economies of arc welding as applied to initial bridge design and result in a more general confidence in arc welding and some degree of standardization of design details and symbols.

The Governing Factors of the Performance of Mild Steel Welded Electrodes*

By BELA RONAY

✦Paper presented at Annual Meeting, American Bureau of Welding, New York, April 28, by Bela Ronay, Senior Engineer (Welding), U. S. Naval Engineering Experiment Station.

TWO years of intensive research work at the United States Naval Engineering Experiment Station at Annapolis, Md., resulted in the definition of the chemical composition and the physical properties essential for mild steel welding electrodes, developed the application of magnetic analysis for non-destructive inspection, and a new instrument, the Arcronograph, for analyzing electric arc welds.

The opinion is expressed that the result of this work will be of far-reaching value to the electric welding world. It is believed that the Arcronograph, a portable instrument, analyzes a weld with equal or greater reliability and at infinitely less cost than the X-ograph.

The Experiment Station's research confirmed the work of other investigators on these two points:

1. Deposition of an electrode through the arc takes place in form of individual drops.
2. Satisfactory electrode performance is conditioned on the uninterrupted regularity of the drops.

The performance of any electrode is revealed when the history of the existence of each individual drop is analyzed. During the brief existence of each drop, two periods may be distinguished, namely, the formation period and the transfer or short circuit period. These periods are known to all who have seen oscillograms of the current and potential changes during the deposition of an electrode. These oscillograms reveal the fact that during the formation period there exists a purely electric arc condition, while the transfer period corresponds to the short circuit period.

The relative length of these two periods within the existence of each individual drop has direct bearing upon the degree of fusion between base metal and deposited metal. The amount of preheating of the base metal or the volume of remelted metal ready to receive a molten drop of electrode metal, is directly proportional to the product of the power input and the corresponding time element of the formation period. In other words, the ideal fusion between base and deposited metal calls for long formation periods, maximum power input and the relatively smallest volume per drop. It follows that the condition commonly called "Penetration" may be expressed as a ratio between remelted base metal and the total volume of the individual deposit.

The difference in the performance of two electrodes of the same diameter and surface finish, but of different composition is found in the relationship of the formation and transfer periods. This relationship is a function of the volume, the temperature and the surface tension of the individual drops.

The temperature of the arc zone is in excess of the melting point of the non-metallic inclusions within a mild steel electrode. When a conglomeration of impurities reaches the arc zone it instantly vaporizes with an explosive force that spatters the molten drop of metal in space.

The chater of the drop-like formation of metal from the electrode was determined by decreasing the rate at which the droplets are normally formed. For the establishment and demonstration of the dropwise deposition, a decelerated drop deposition was used. This method employs a graphite plate instead of steel, as base material, thus permitting the use of current values of one-half to five-eighths of the normal. Accordingly, the deposition is slowed down and the individual drops may be separated with ease.

The history of each drop was recorded by means of an accelerated strip chart ammeter.

The ability of an electrode to perform depends upon the following factors:

1. Chemical composition.
2. Freedom of impurities.
3. Grain structure.
4. Surface finish.

An analysis of the influence of the above factors upon electrode performance is as follows:

1. Chemical Composition.—The carbon content of mild steel electrodes is the most important factor as a component in influencing its performance, providing that all other ingredients are present in a normal proportion. The carbon content determines the melting point of the metal, thus regulating its viscosity. The surface tension of the molten metal at the tip of the electrode is proportional to its viscosity and these two factors determine the volume of the drop for a given electrode diameter. These statements are familiar to all versed in physical chemistry.

2. Freedom of Impurities.—The melting point of non-metallic inclusions is lower than that of the steel of the electrode. At the temperature of the arc, non-distributed inclusions explode, disturbing the regular succession of the drops. Such disturbance leads to oxidation of the freshly deposited metal in case of bare electrode welds and trapping of slag in case of covered electrode welds.

3. Grain Structure.—The grain structure of an electrode of a given chemical composition influences its specific resistance and thus may change the required current density from electrode to electrode in case of non-uniform grain structure.

4. Surface Finish.—In case of bare or thinly coated electrodes, the volume of the individual drops, as well as the frequency of their formation and deposition, is almost entirely a function of their chemical composition. In case of covered electrodes, both drop volume and frequency are altered. With covered electrodes, higher current densities may be used, thus raising the molten metal to a higher temperature. The higher temperature changes both the viscosity and the surface tension of the molten metal at the tip of the electrode. In addition, in case of a properly functioning covered electrode, the covering is consumed a trifle slower than the core, thus a miniature crucible is provided at the tip of the electrode for retaining a drop that is larger than would form at the end of the same electrode were it left bare or only thinly coated.

The investigation used the following methods for the determination of electrode performance:

The principle of Magnetic Analysis was used to deter-

* Results of the Research Work performed at the U. S. Naval Engineering Experiment Station, Annapolis, Md.

mine the chemical composition and microstructure of metallic electrodes as associated with satisfactory electrode performance. This is a non-destructive method that compares the permeability of an unknown specimen to a known standard. The instrument indicates a modified sine wave by means of an oscillograph and the interpretation of the modifications of the sine wave indicates the similarity of characteristics of the electrodes compared. The indications are qualitative if the standard of comparison is unknown; when the chemical and physical characteristics of the standard are known, then the indications of the oscillograms become quantitative. The oscillograms show a change of amplitude, shape and change of phase of the original sine wave. This system was selected because of the importance of the permeability factors as governors of the electrode performance.

The study of the drop deposition charts, together with the conclusions drawn from the observation of the drop deposition, led to the development of the Arcronograph.

The Arcronograph is an electrical instrument that automatically integrates and records the time relationship of the formation periods and short circuit periods of each drop throughout the entire consumed length of each electrode as a function of the potential conditions that exist during each corresponding period. Thus the record of this instrument furnishes information concerning the continuity of the weld, the penetration ratio, the arc conditions maintained and, finally, the current conditions.

The records are qualitative in general, but are quantitative when applied to work performed by electrodes of known characteristics. The Acronograph may serve as an instrument to quickly and inexpensively evaluate the performance of any electrode. The Arcronograph furnishes information concerning the quality of the weld.

The Arcronograph consists of a strip chart recording ammeter or voltmeter, actuated by the plate output of a three-element vacuum tube. The vacuum tube serves as high speed relay to differentiate between the high voltage of the formation periods and the low voltage of the transfer periods of each individual drop. The circuit is designed and so calibrated that there is no plate output during the short circuit or transfer periods. Thus, the plate output is an intermittent current or rather a series of current impulses only. The inertia of the pointer of the recording instrument does not permit its following the rapid pulsations of this current and so it assumes a position that corresponds to the mean current value of the pulsations and it registers on an arbitrary scale of 100 divisions the relationship between formation periods and transfer periods. Short circuits of more than split second duration are registered as zero values, while abnormally long arcs or open circuit conditions are recorded as values of 100.

The above disclosures enabled the investigators to define the requirements the electrode manufacturers will have to comply with to enable them to supply uniformly performing high grade electrodes. These requirements are:

1. Chemical composition held within reasonably close limits.
2. Freedom of impurities, permitting the presence of a small amount of non-metallics uniformly distributed.
3. The grain structure must be uniform. The material must be fully recrystallized.
4. The covering of covered electrodes must perform to permit the required uninterrupted minimum formation period-transfer period ratios, the Arcronograph ratings, that were found necessary for satisfactory performance.

Electrodes that will comply with the specifications thus defined will yield deposited metal that will comply with the physical requirements for such. The proposed method of inspection of bulk shipments includes the use of magnetic analysis as an unerring way of checking the uniformity of the electrodes. Bead deposit tests, recorded by the Arcronograph, are proposed to furnish information concerning the uniform performance of the covering.

The Author takes this opportunity to express his gratitude to Captain H. R. Greenlee, U. S. N., Director of the Experiment Station, and Lieutenant-Commander V. H. Godfrey, U. S. N., Executive Officer, for the aid and encouragement received during this investigation.

Arc-Welded Joints in Pipe-Line Prove Stronger than Pipe Metal

By A. F. DAVIS

✦Mr. Davis is Vice-President of The Lincoln Electric Co.

AFTER its first year of use, 149 miles of the 210-mile Southern Fuel pipe-line from Kettleman Hills to Long Beach, California, offer additional proof of the advantages of electric welding.

One hundred eighteen miles of pipe in the 26-in. line were welded by the shielded arc process by H. C. Price, Inc., of Bartlesville, Oklahoma, using gasoline-driven welders.

With cold weather contraction added to normal operating gas pressure, the arc-welded joints were put to a severe test. In one instance, as shown in the accompanying photograph, for reasons not determined the pipe failed under 250-lb. gas pressure. The size of the hole in the ground is an indication of the tremendous force with which the gas was released. None of the adjacent welds showed any signs of fracture.

WELDING SURVEY

A Monthly Review of Some Important Phases of Welding

Track Welding Practice Shows Marked Advance

By WILLIAM SPRARAGEN

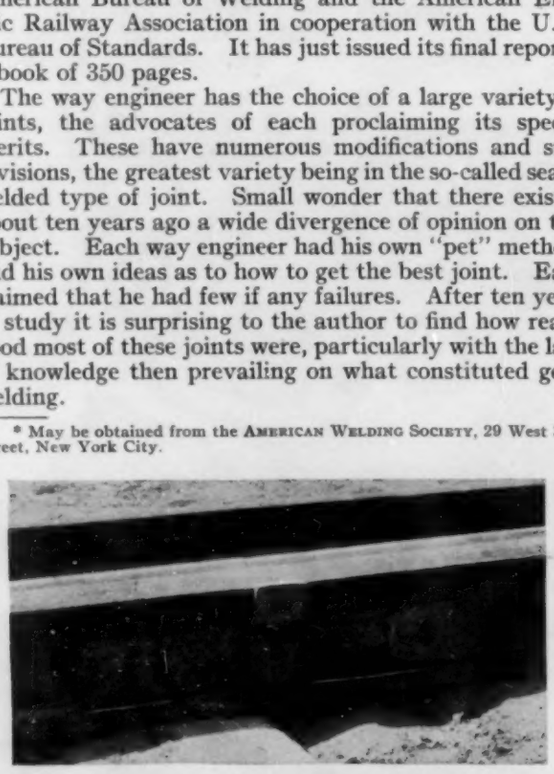
✦Mr. Spraragen is Secretary American Bureau of Welding. Work of the Committee on Welded Rail Joints has done much to dispel erroneous ideas and to point the way to better practice. This review was prepared for the Transit Journal.

WELDING processes in use by street railways may be conveniently divided into two phases: namely, welding of various kinds which is done in the shop and track welding. The problems involved are entirely different and the present article is confined to welding processes coming under the jurisdiction of the way engineer. By far the most important of these is the production welding of rail joints.

In the discussion that follows reference is made to the work of the Welded Rail Joint Committee. This committee was organized some ten years ago jointly by the American Bureau of Welding and the American Electric Railway Association in cooperation with the U. S. Bureau of Standards. It has just issued its final report,* a book of 350 pages.

The way engineer has the choice of a large variety of joints, the advocates of each proclaiming its special merits. These have numerous modifications and subdivisions, the greatest variety being in the so-called seam-welded type of joint. Small wonder that there existed about ten years ago a wide divergence of opinion on this subject. Each way engineer had his own "pet" methods and his own ideas as to how to get the best joint. Each claimed that he had few if any failures. After ten years of study it is surprising to the author to find how really good most of these joints were, particularly with the lack of knowledge then prevailing on what constituted good welding.

* May be obtained from the AMERICAN WELDING SOCIETY, 29 West 39th Street, New York City.



Appearance of a Resistance Bar Weld before Grinding, Showing Head Support

A Butt-Type Resistance Weld after Breaking the Rail Ends in an Impact Test

There are many difficulties involved in making a first-class joint. Some are fundamental and not easily overcome and others are due either to ignorance or perhaps false economy on the part of way engineers. Among the fundamental difficulties are the relatively high carbon content (0.75 per cent) of the rail, which does not lend itself readily to welding without special precautions and difficulties because of the position of welding. Further complications sometimes met are traffic and the necessity for maintenance of schedules. Other difficulties, not so fundamental but still important, are lack of suitable apparatus, comparatively unskilled welding operators and even supervisors and the "pet" theories of some way engineers.

Cast Joint

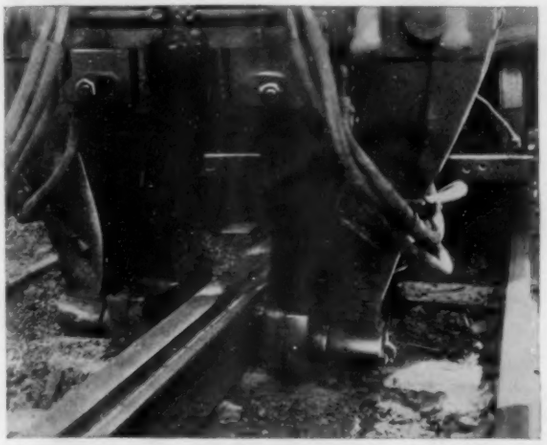
The cast weld is perhaps the oldest type of permanent joint, popular fifteen years or more ago. The making of cast welds was spectacular, involving a foundry on wheels with all the attending paraphernalia. This method has been discarded except occasionally for compromise joints in special track work. In its day it served its purpose well and from many view-points was considered excellent.

Bar Joint

The resistance method is used in making two quite different types of joints, the bar and butt welds. The bar weld has an electric resistance considerably less than that of unbroken rail. In a series of tests made by the Welded Rail Joint Committee its ultimate tensile strength was found to average 370,000 lb. and under bending load of 75,000 lb. its deflection was no greater than that of the unbroken rail. Under repeated impact from a weight of 400 lb. dropping a distance of 6 in. it withstood an average of 343,000 blows before failure. These blows caused actual stresses of the magnitude of more than $2^1/_2$ times that which the joint would be like to receive under severe service conditions either due to cupping or flat wheels. An accompanying illustration shows the method of welding this type of joint.

Butt Joints

The butt joint was shown by tests by the Welded Rail Joint Committee to approach the qualities and properties of the unbroken rail. The handicap of this type of joint is the cumbersome special equipment needed although if a large number of joints are welded at one time the cost per joint is reasonable.



Resistance-Type Bar Welds Require Special Apparatus, but Make Excellent Joints

The butt joint, on 7-in. girder rails, has an average tensile strength of 870,000 lb. and under repeated impact its resistance to blows was practically the same as that of the unbroken rail. In most of the physical tests it more nearly approached the quality of the original rail than any other type of joint.

In making the butt joint no special preparation of rail ends other than having them square and clean is necessary. A flux of molten borax glass is used, averaging about 3 lb. per weld.

The apparatus is mounted on two 18-ft. motor driven trolley cars. The first car contains a 30-kw. alternating current generator, for supplying the welding current, direct connected to a 64-hp. motor, an air compressor for supplying air and oil to an oil burning furnace for melting the flux which is located at the front end of the car. This car also contains tanks for air and fuel oil storage, switchboard with necessary instruments, etc., and suitable means for raising the two rail clamps from the rail and transporting them from job to job. The rail clamps are mounted on rollers at either end to which the weight can be transferred to move them from joint to joint. These clamps are provided with hydraulic pumps supplying the pressure to force the rails together in the process of welding and means for clamping the terminals of the generator to them. The second car contains an oven for drying the cores and a molder's bench for making the cores. At the rear end of this car two grinding machines are carried for finishing the upper surface of the rail after the weld has been made. Current for operating the apparatus is taken from the street railway trolley wire. Voltage of welding current varies from 80 to 40 volts, amperage at latter voltage from 1400 to 1600.

Rail ends are confined in rail clamps by means of wedges and are held rigidly to line and surface. The parts of the clamp engaging the rails are insulated from each other and the terminals of the generator are clamped to these parts. The rails are set with their ends about $^{3}/_{8}$ in. apart preparatory to welding. Dry molds or cores, in four pieces, are set around the rail ends forming a receptacle for confining the flux so that it comes in contact with the end surfaces of the rails only. The generator is started with the voltage set at 80, the molten borax is then poured into the mold, establishing a path for the current from rail to rail. In its passage the borax becomes heated more and more and the higher its temperature the greater its conductivity, so that the voltage is then cut down to 40 volts. When the rail ends reach a welding heat their resistance increases to such an extent that the voltage rises again. At this point the welding current is cut off and simultaneously the rails are forced together under a pressure of 5000 lb. per sq. in. This pressure is maintained for about 5 minutes until the metal has cooled below its critical temperature.

Rails are not preheated.

Seam-Welded Joint

The seam-welded joint, which is a descendant of the bolted and riveted joint, still possesses many of its inherent advantages and disadvantages. Essentially the procedure is the welding of two joint plates or fish-plates, as they are generally called, to the ends of the rail. Accepted technique calls for accurate fitting of the rail heads and bringing them together under pressure. The variations in vogue are so great that it would be difficult, if not impossible, to enumerate them all. Special merit has been claimed for the way in which the heads were brought together, the method of bolting or riveting, the exact contour and shape of the fish-plates, the use of a wide variety of base plates, special techniques in welding, special wires, fluxes and welding processes.

Although the author has not had the courage to say so before any large group of way engineers he is of the opinion that many of the theories and special claims involved have no scientific basis. For example, to bring the rail heads together for a tight fit some use soft iron inserts, others cut the rail heads accurately with a saw and still others think it necessary to miter the rail heads. Others claim special benefits in having the rail heads separated slightly. All of these cannot be the best way. Probably assuring that the rail heads are cut straight and brought tightly together is as good a method as any.

The available processes of welding are: the carbon arc hand-feed system, the carbon arc rod-in-position system, the metallic arc or atomic hydrogen. The investigations of the Welded Rail Joint Committee show that satisfactory results may be obtained by each of these welding methods. Using the carbon arc the committee found that more uniform results can be expected from the hand-feed system than with the rod-in-position. The tests demonstrated conclusively that the human equation was as large as or greater than any other variable. The author cannot recommend too strongly that only thoroughly trained, experienced operators be employed to make the seam-welded type of joint.

To secure a proper weld suitable penetration at the root of the fillet weld is essential. This penetration depends in some measure on the type of joint plate used, it being easier to weld certain types than others. When the committee started its tests some way engineers claimed special merit for the contour of the bearing surface and called for great refinements in its exact preparation. As a matter of fact this exact surface is destroyed to a depth of at least $^{1}/_{16}$ in. by the welding process. In general, it is recommended that fish-plates be such as to facilitate penetration by the welder at the root of the weld and readily permit the deposit of a fillet weld in the form of a right triangle with $^{1}/_{2}$-in. legs. Weld deposits in two layers have been found preferable, as the second layer refines the grain of the first and in a measure relieves any locked-up stresses.

Staggering of the seams so that they will not end in the same plane with reference to the cross section of the joint has been recommended by way engineers for a number of years. Their claims were substantiated by tests of the committee. The staggering should be more than 1 in. Where trouble from breaking of the rail at the end of the seams has been experienced this method is particularly advocated.

Mention had been made of the fundamental difficulty of welding high-carbon material. Welding engineers generally prefer mild steel with a carbon content of 0.20 or less. Unfortunately this low-carbon steel is not desirable for rails. Here the carbon content is about 0.75, although the fish-plates may be 0.20 carbon or less. The process of welding burns out some of the carbon from the rail and produces a hard brittle zone adjacent to the weld, to eliminate which preheating or postheating is necessary. A few way engineers take the trouble to do this as best they can in the street railway track. With the carbon arc, atomic hydrogen or gas flame, partial preheating or postheating with some beneficial results can be obtained by using the source of welding heat for the purpose. There is no point in preheating to more than 900° F., and the more nearly this temperature is approximated the better the results.

In order to prevent or minimize locked-up stresses and brittleness in the joints a sound ductile weld seam is desirable. This may be obtained in a variety of ways. A few of these are: (1) use of fluxes, (2) the use of covered electrodes, (3) atomic hydrogen and gas welding and (4) welding from both ends at the same time and peening each layer while hot.

It is probably unfortunate that the welded fish-plate was patterned so closely after the bolted joint. When subjected to tension the load is not equally divided among the various seams. In the tensile tests of this type of joint made at the Bureau of Standards the lip top seam generally carried more than its share of the load. This led the Bureau of Standards to suggest that for a balanced design the seam lengths should be proportional to the areas for which they are to transfer loads from rail to rail. Although only one joint was made up with seam lengths proportional to the load, the base seams being only half the length of the top seams, it was found that this joint did not break in the welds and withstood a greater load than other specimens of the same series. Nearly all of the seam-welded types of joints tested had excellent conductivity and resistance to deflection.

The value of base plates was not clearly demonstrated. The difficulty is that the loads carried by the welds are not distributed uniformly. The tensile strength at failure was no greater when base plates were used than when they were omitted. Under repeated impact tests the base plates are usually knocked off first, after which the joint acts as if none were used.

The desirability of suitable apparatus becomes particularly important in metal arc welding. Resistance in series with an electrode is undesirable from several viewpoints. Aside from wasting most of the power it throws a serious handicap on the operator in producing a good weld. Modern welding generators are designed to give special combinations favorable to welding, such as drooping voltage characteristics, constant energy or current, quick recovery and stabilization of the arc generally.

Breakage of a Thermit Joint after Repeated Impact

A Pressure-Thermit Welded Joint of a Type Made in Germany

Thermit Joint

Thermit joints are steadily increasing in favor. In making the Thermit joints tested by the Welded Rail Joint Committee, the procedure followed was essentially that recommended by the manufacturer of the materials used. Some had the usual separate inserts and others the attached insert formed by undercutting the rail head. No essential difficulties were observed in the test results on the two types of joints. The electrical conductivity is usually the same as that of the plain rail. The ultimate tensile strength of the Thermit joint for a 7-in. girder rail is about 510,000 lb. Under severe repeated impact tests, the joint gave a good account of itself. If properly made it will offer no difficulties in service.

There is some variation in the methods of making Thermit rail joints in this country and abroad. In Germany, for example, the joint has been used to a large extent in open track work. To a lesser extent it is being tried in this country. The chief difference is the bringing of the ends of the joint, particularly the heads, together under pressure at the proper moment when the surfaces are in a plastic condition, thus forming a pressure weld of the rail heads with physical properties the same as those of the resistance welded butt joint, which approximate closely those of the rail itself. The uniformly good results obtained with the Thermit joint at a reasonable cost account in a considerable measure for its increasing popularity.

Oxyacetylene

The general utility of the oxyacetylene torch for cutting metals on the right of way and in the shop is so well known that it needs no special mention. It is most useful for repairs, salvage and reconstruction work. A great deal of this work and welding with the gas torch, of vital interest to the way engineer, is done in the shops. For example, lugs of pressed metal for split switch points are made in the shop by one street railway from old materials. Several pieces of trackage may be cut to the correct shape from standard rail and welded by the oxyacetylene process. The welding of copper bonding with a copper welding rod is a very common application of the process among electric railways. A high electrical conductivity is assured when the bonding terminals are welded to the rail and the joint is a permanent one. In cutting rails the cut is usually started at the flange, continued through web and finally carried through the ball of the rail.

Gas welding is being used with perfect satisfaction by steam railways for welding continuous track in tunnels, terminals, highway crossings and other locations where a continuous rail is highly desirable. The process has not yet been promoted for street railway tracks.

FROM ABROAD

Informal Communications of the Committee on Welding of the Verein Deutscher Ingenieure

†Translated through the courtesy of the Babcock & Wilcox Co.

Program of the Committee on Welding

Problem	Worker	State of Research Work on April 1, 1931	Publication
1. Formulation of rules for valuating the capacity of acetylene welding apparatus	Sauerbrei	Work in progress	
2. Influence of the generation process in the generator on the purity of acetylene	Rimarski	Completed	
3. Experiments with water headers, particularly central water headers with a view to determining the safety of the header itself in the case of a back-fire or of an explosion inside the header	Rimarski	Completed	1. Autog. Metallbearb., V. 20 (1927), Nr. 22 & 23 2. Schmelzschweissung, 8 (1929), Nr. 7, 8 & 10 3. Autog. Metallbearb., V. 24 (1931), Nr. 8, 9 & 10 4. Jahresberichte der Chem.-Techn. Reichsanst., Nr. V, VI, VII, VIII
4. Exact measurements of the temperature of the oxyacetylene welding flame	Henning	Completed	1. VDI-Zeitschrift v. 72 (1928), Nr. 50, p. 1828 2. Autog. Metallbearb., v. 21 (1928), Nr. 23, p. 330
5. Influence of the arrangement of nozzles on the quality and economy of cutting with oxygen	Richter–Rimarski	Completed (executed by C. Assmann)	1. Autog. Metallbearb., v. 24 (1931), Nr. 1 and 2
6. Investigations of welding and cutting torches, overcoming of faults, prevention of back-fires	Rimarski	Work in progress (identical with problem No. 40)	
7. Experiments with cutting torches, most favorable thickness and flow velocity of the jet, oxygen pressure and thickness of the work piece	Hilpert	Completed	1. Techn. Zentralbl., Aug. 25, 1930, Schweisstechn. Rundschau 2. Autog. Metallbearb., 1931, Nr. 1 and 2 (Arbeit v. Assmann) (Work by Assmann)
8. Formulation of rules for valuating the apparatus used in electric welding	Lottmann	Completed	1. Zwanglose Mitteilungen des Fachausschusses für Schweisstechnik, February 1931, Nr. 17 2. ETZ (Elektro Technische Zeitschrift) (1930), p. 652 3. Sonderdruck des Verbands Deutscher Elektrotechniker (Reprint of the Association of German Electrical Engineers), VDE 486, RESM 1931
9. Investigations on the transport of material by the welding arc and on the physical properties of the latter	Hilpert	Completed	1. VDI-Zeitschrift of June 8, 1929 2. Techn. Zentralbl., Aug. 25, 1929, Nr. 16
10. Photographic pictures of the electric welding arc with the view later to undertake magnified time exposures	Strelow	Completed	3. Journal of the American Welding Society, XII, 1929
11. Relations between the degree of purity of the acetylene and oxygen used in welding and cutting torches on the economy and quality of the welded seam or cut	Rimarski	Completed	1. Autog. Metallbearb., v. 19 (1926), Nr. 23 2. "Schweissen, Schneiden und Metallspritzen mittels Azetylens" ("Welding, Cutting and Metal Spraying by Means of Acetylene") (1927), Verlag von Marhold, Halle 3. Forschungsarbeiten auf dem Gebiete des Ingenieurwesens (Research in Engineering), Heft 317 (Rimarski, Kantner, Streb) 4. Jahresberichte der Chemisch-Technischen Reichsanstalt, Nr. V and VI (Yearly Reports)

Problem	Worker	State of Research Work on April 1, 1931	Publication
12. Valuation of the pressure difference between acetylene and oxygen in the torch on the quality and economy of the welded seam	Rimarski	Completed	1. Autog. Metallbearb., v. 23 (1930), Nr. 5 & 6 2. Forschungsarbeiten auf dem Gebiete des Azetylens, 4. Folge (Research in the Field of Acetylene, 4th Series) (1930), Verlag K. Marhold. Halle 3. VDI-Zeitschrift, v. 74 (1930), Nr. 12 4. Jahresberichte der Chemisch-Technischen Reichsanstalt (Yearly Reports of the Chemisch-Technischen Reichsanstalt), Nr. VII & VIII
13. Investigation on the impurities of acetylene and on how they can be chemically bound and made harmless; impurities inside and outside of the welding flame, water content of the gases	Rimarski	Completed	1. Autog. Metallbearb., v. 23 (1930), Nr. 17 & 18 2. Jahresberichte (Yearly Reports) der Chemisch-Technischen Reichsanstalt, Nr. VII 3. Dissertation by Joos, Technische Hochschule, Braunschweig (soon to be published)
14. Drawing up of rules for valuating bare welding bars (welding wire)	Kantner	Completed	1. Von der Reichsbahn Verordnet: (Ordinance of the Imperial Railway Co.)—Vorläufige besondere Bedingungen für die Lieferung von Schweissdraht für Flussstahl (Temporary Special Specifications for the Supply of Welding Wire for Welding Mild Steel) 2. Auszug in Zwanglose Mitteilungen (Abstract in Informal Communications), Nr. 16, p. 9
15. Influence of the coatings of welding bars (welding wire) on the quality and economy of the weld	Kantner	Work in progress	1. Zwanglose Mitteilungen (Informal Communications), Nr. 16
16. Influence of the wrappings of welding bars on the quality and economy of the weld	Baumgärtel	Completed	1. Forschungsarbeiten auf dem Gebiete des Ingenieurwesens (Research in Engineering) Heft 336 (Baumgärtel) 2. VDI-Zeitschrift, v. 75 (1931), p. 53
17. Which changes take place in the material of the work piece and in that of the electrodes by the action of the electric arc	Hilpert	Work in progress	
18. Formulation of rules for the carrying out of tensile and bending tests of welded pieces	Bardtke	Work in progress	1. Erster Entwurf in Nr. 7 der Zwanglosen Mitteilungen (First Draft in No. 7 of the Informal Communications), p. 2 2. See also: Bardtke, Gemeinfassliche Darstellung der Gesamten Schweisstechnik (Popular Presentation of the Whole Field of Welding)
19. Investigation of the conditions of current intensity and tension during welding when using D.C. current	Bung	Completed	1. Elektrotechnik und Maschinenbau (1928), Heft 22 2. Schmelzschweissung (1929), Heft 12, p. 246
20. Investigation on the advantages and disadvantages of welding with D.C. or A.C. current	Bung	Completed	3. Elektroschweissung (1930), Heft 3, p. 45 4. VDI-Zeitschrift (1930), Heft 46, p. 1557
21. Investigation into the possible savings in wages, weight and types of sections by completely welding a 200-ton oil lighter	Strelow	Completed	1. Elektrotechnik und Maschinenbau, Special Number (1928) 2. Jahrbuch (Year Book) der Schiffbautechnischen Gesellschaft (1931)
22. Development of a portable apparatus for investigating welds by means of X-rays	Kantner	Work in progress	1. Elektrotechnik und Maschinenbau (1928), Nr. 22 2. VDI-Zeitschrift (1930), Nr. 3 3. VDI-Zeitschrift (1930), Nr. 41 4. VDI-Zeitschrift (1931), Nr. 13 5. Elektroschweissung (1930), Nr. 10 6. Giesserei (1930), Nr. 18 7. Bautechnik (1931), Nr. 1
23. Comparative tests with riveted and welded girders regarding the cost for wages and material	Strelow	Work in progress	Report will be published in the near future in "Elektroschweissung"
24. Investigation on a rational annealing treatment of wear-resisting built-up welding	Behrens	Work in progress	
25. Investigations on the weldability of tubes and plates of chrome-molybdenum steel	Kuchel	Work in progress	Paper by Beissner: On the Influence of Gas Fusion Welding on the Vibration Strength (to be published shortly in the VDI-Zeitschrift)
26. Investigations on the long time strength of welded pipe constructions	Kuchel–Hoffmann	Work in progress	
27. Investigations on the effect of dynamical stresses on welding	Hoffmann	Work in progress	Book by Hoffmann

Problem	Worker	State of Research Work on April 1, 1931	Publication
28. Formulation of rules for the uniform conduction of welding courses	Schimpke	Completed	First Draft in Nr. 5 of the Informal Communications (Zwanglose Mitteilungen) final draft in No. 8 and No. 9 To be had from the business office of the Fachausschuss für Schweisstechnik (Professional Committee on Welding Engineering at the VDI) and also from the Verbandes für Autogene Metallbearbeitung (Association for Autogenous Metal Working)
29. Support of training courses for welding instructors and engineers	Grunewald	Completed	
30. Support of training courses for welders and workmen	Grunewald	Completed	
31. Compilation of uniform symbols and designations in welding engineering	Hilpert	Completed	1. Maschinenbau, v. 4, Heft 20, October 1, 1925 2. DIN-Sheets (1910, 1911, 1912)
32. Compilation and keeping of special statistics on accidents occurring in welding	Kleditz	Work in progress	Report in Informal Communications (Zwanglose Mitteilungen), Nr. 8, p. 5 and Nr. 18, p. 9
33. Investigations on the behavior of various kinds of glass toward the harmful action of the radiation from electric welding arcs	Kleditz	Completed	Schmelzschweissung, February 1927, Nr. 2
34. Investigation of the spectrum of the electric welding arc for the kind of radiation and the action of the various kinds of radiation on the body of the welder	Kleditz		
35. Explosion-proof lubricant for the cocks on torches	Rimarski	Completed	1. "Schneiden und Schweissen mit Azetylen" ("Cutting and Welding with Acetylene") (1929), Verlag Karl Marhold, Halle 2. Autog. Metallbearb., v. 22 (1920), Nr. 9 3. Jahresberichte der Chemisch-Technischen Reichsanstalt (Annual Reports of the Imperial Chemical-Engineering Institute), Nr. VII & VIII 4. The latest results are going to be published in the near future in Autog. Metallbearb. as well as in the VDI-Zeitschrift
36. Abstracts from the technical literature on welding	Adrian	Current work	
37. Publication of informal communications (Zwanglose Mitteilungen) and the spreading of the results of research work by writings	Adrian	Current work	(See Below)
38. Experiments on the welding of steel of a high carbon content	Stursberg	Work in progress	Paper to be read at the general meeting of the VDI at Cologne (1931)
39. Manufacture and calibration of an electrodynamic measuring instrument for arc welding by means of D.C. current by using borrowed apparatus	Flamm	Completed	1. Zentralblatt der Hütten- und Walzwerke: v. 31 (1927), Nr. 46 & 47; v. 32 (1928), Nr. 25 2. Die Schmelzschweissung, v. 8 (1929), Heft 1 & 3 3. Mitteilungen der Technisch-Wissenschaftlichen Vereine Mitteldeutschlands (Communications from the Scientific and Engineering Societies of middle Germany) (v. VI, Heft 7)
40. Rules for the testing of torches, particularly of injector type torches operated on low pressure acetylene	Rimarski	Work in progress	Publications in part: 1. Autog. Metallbearb., v. 23 (1930), Nr. 8 2. Jahresberichte der Chemisch-Technischen Reichsanstalt (Annual Reports of the Imperial Chemical-Engineering Institute), Nr. VIII
41. Determination of the most favorable discharge velocity (and if necessary of the most favorable cone shape) for hand welding and various thicknesses of the material	Rimarski	Work in progress	
42. Relation of the economy in welding with the oxyacetylene flame and of the quality of the welded joint to the nature of the material of the welding wire and of the material to be welded	Rimarski	Work in progress	
43. Magnetic testing apparatus	Kettner–Unger	Work in progress	
44. Impact tests on welded connections of steels St 37, St 48, St 52	Hoffmann–Fiek	Work in progress	
45. Large scale tests for determining the long time strength of welded joints	Schaper		

Publications: Problems 36 and 37.

1. Zwanglose Mitteilungen (Informal Communications), running, thus far Nos. 1 to 18.
2. "Ausgewählte Schweisskonstruktionen" ("Selected Welding Constructions"): v. 1, Steel Construction (Bondy); v. 2, Machine Construction (Haas).
3. 1 Sonderheft (special number) (1926) and 2 Fachhefte (Professional numbers) (1929 and 1930) of the VDI-Zeitschrift.
4. Denkschrift an die Ministerien: "Die Bedeutung der neuzeitlichen Schweisstechnik für die Künftigen Ingenieure" (Memoir to the Ministries: "The Significance of Modern Welding Engineering to the Future Engineers") (1928).
5. Sonderdruck des Fachausschuss für Schweisstechnik: "Amerikanische Lehrhefte für Schweisskurse" (Pamphlet by the Professional Committee for Welding Engineering: "American Lecture Notes for Welding Courses") (1928).
6. Regein für die Bewertung und Prüfung von Gleichstrom-Lichtbogen-Schweissmaschinen (siehe auch Aufgabe 8) (Rules for Valuating and Testing D.C. Arc Welding Machines (see also problem 8)).
7. Vorläufige Besondere Bedingungen für die Lieferung von Schweissdraht für Flussstahl (Deutsche Reichsb.-Ges.) (Temporary Special Specifications for the Supply of Welding Wire for the Welding of Mild Steel (German Imperial Railway Company)).
8. Richtlinien für Schweissversuche (Rules for Welding Tests) (Bardtke).
9. Richtlinien für Schweisskurse (Rules for Welding Courses) (Schimpke).
10. Richtlinien für Geschweisste Stahlbauten (Rules for Welded Steel Structures).
11. Richtlinien für Geschweisste Gasrohrleitungen von Mehr Als 200 mm. Durchmesser und Mehr Als 1 Atü Betriebsdruck (Rules for Welded Gas Pipe-Lines of More Than 200 Mm. (about 8") Diameter and More Than 1 Atü (14.223 Lb./In.²) Gage Pressure.) (VDI-Verlag, 1930.)
12. Sonderheft von "Elektrotechnik und Maschinenbau" (Special number of "Elektrotechnik und Maschinenbau"), v. 46, Heft 22 (May 27, 1928).
13. Schweisstechnisches Fachwörterbuch (Deutsch-Englisch-Russisch) (Dictionary of Welding Terms—German, English, Russian). (VDI-Verlag, 1931.)
14. Aufsätze und Berichte in Fachzeitschriften (Articles and Reports in Technical Periodicals).

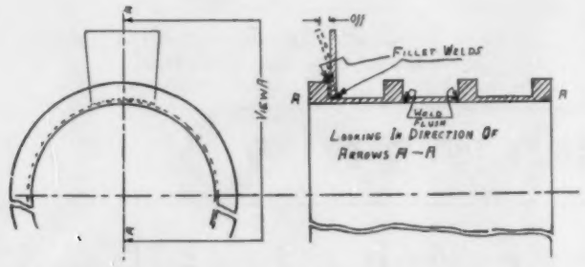
COMMUNICATIONS

Expansion and Contraction

"I would suggest that we have some space in the Journal devoted to discussion of some of the articles which appear in our Journal. Most of the articles are written by experts who work in the laboratories. Their findings, while correct, must need modification or further development before application on actual jobs in the shop. For example, Mr. C. J. Holslag has an excellent article in the January issue dealing with the Shielded Arc Process. Now, after reading this article one may get the idea that peening will take care of all expansion and contraction. I do not think this is correct. I have seen work done on boiler plate where we had a first-class weld using 1/4 in. covered wire with 300 amps., and when the job was completed it was so badly warped we had to heat with torch and straighten. The next time we got the same kind of job to do we tack-welded braces onto the part to hold it in place and that ended the warping. Please note carefully on the sketch where the warpage took place. If I may, I would say these gentlemen writing articles on covered wire should go more fully into details concerning contraction and expansion."

J. W. BLAKEY, Turtle Creek, Pa.

"Layer annealing is the entire secret of good results with covered wire. This can be done in the natural course of welding or by adding an extra layer or by our normalizing or cutting rod if an extra layer is objectionable. Covered rods properly used make a better weld. There is no doubt about it. Incorrectly used they are no worse than other methods except for warping and stresses which, perhaps, should be relieved in some manner and I guess the industry will have to go through the period of acquiring this covered welding rod procedure control the same as it has gone through the art of first laughing at welding and then using it where it shouldn't and settling down to engineering principles. Covered welding rod, especially with alternating current properly used, makes a far better and far cheaper product, but the proper use cannot be acquired by reading a book any more than the game of billiards could be learned in such a manner.



"The first layer of arc-weld deposit and all layers not normalized by a subsequent layer or cutting normalizing layer are in a transition stage, ready to change but *not changed* by any advertisement to that effect. Do not confuse the oven treatment of heavy pressure vessels with this layer normalizing treatment. The oven treatment is to even up or relieve heat stresses while the layer treatment changes the grain structure."

C. J. HOLSLAG, Electric Arc Cutting & Welding Co.

First Arc-Welding Generator

"In the JOURNAL OF THE AMERICAN WELDING SOCIETY, December issue, pages 31 and 32, appears a 'Discussion of Paper by C. A. Wills on Welded Rolled Steel Design for the Iron and Steel Industry.' In said article on page 32 appears the following:

> 'The writer's experiments in salvaging steel castings were responsible for the first motor-generator set made in this country exclusively for arc-welding purposes. That pioneer unit was made by the General Electric Company in 1909.'

"We think that such a broad and unqualified statement should be corrected as the C. & C. Electric Company which we acquired some years ago started selling motor-generator sets made exclusively for welding in 1905, one of the early installations being at the Chester Steel Castings Company, Chester, Pa., which set was put into service in April 1905."

JAMES BURKE, President, Burke Electric Company

"Mr. Burke's correction prompts me to express sincere regret for what, evidently, was a serious error in a comment made by me, quoted correctly by Mr. Burke. I made the statement in good faith; believing from my recollection of circumstances and declarations made to

me in 1909 by technical representatives (presumably well informed), in the service of two very large concerns making electrical apparatus, that the welding unit ordered by the Commonwealth Steel Co. in the year mentioned was the first of its kind made in this country for the purpose indicated.

"Interesting problems were encountered after placing the original order, tending strongly to emphasize what appeared to the Commonwealth Steel Co. to be the pioneering nature of the project for reducing the direct voltage of the plan from 220 to 80 for welding. Although the General Electric Co. accepted the order for the entire equipment, it sublet the controller panel to the Electric Controller and Manufacturing Co. Subsequently, the General Electric Co. supplied its own control panels for outfits substantially like the original installation, also purchased by the Commonwealth Steel Co.

"I would not knowingly take credit for work done by others. Therefore, while regretting my error, I am glad to be corrected. Perhaps Mr. Burke will feel lenient, since the incident brings to public notice the much earlier pioneering effort that seems to have been made by individuals previously connected with the C. & C. Electric Co."

R. A. BULL, Director, Electric Steel Founders' Research Group.

HOW TO WELD IT

Salvaging a Fuel Hog

By **GEORGE SYKES**

✦Mr. Sykes is connected with the Haynes Stellite Company.

THE ability of the oxyacetylene process to salvage worn or broken parts has been demonstrated in literally thousands of applications and many parts which apparently are good for only the scrap pile have been saved by means of this process. Such reclaimed parts not only have been put back in service at a cost far below that for new parts but also have been often shown to have many times the life of new parts.

Recently a Diamond hog, part of the equipment of a large lumber mill located in the northwest, was saved by means of rebuilding with the oxyacetylene blowpipe. This hog, a machine with revolving knife cutters for grinding up edgings and slabs, had given continuous service for 22 years and had become very badly worn. In addition to the wear, a sledge hammer, which had accidentally dropped into the machine had broken out a triangular section constituting a large portion of the anvil base.

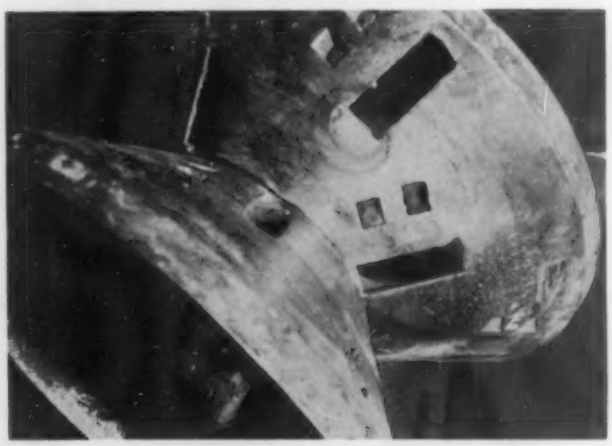
The accompanying illustrations demonstrate clearly the procedure that was followed in reclaiming the hog. The first photograph shows the cast-iron section partly enclosed in a fire-brick furnace in which it was heated preparatory to welding and building-up. The worn anvil base is shown as the horizontal triangular surface at the rear of the casting. This section had, in the course of 22 years, worn down approximately 1 in. This extreme wear made it quite impossible to secure a proper adjustment of the knives attached to the anvil and to the rotor, cutting down to a great extent the efficiency of the machine.

The Worn and Broken Anvil Base Ready for Reclamation

A triangular piece of $^{7}/_{8}$-in. steel plate approximately 11 in. on a side was welded into position at the rear of the casting to replace the shattered portion of the anvil base. By using carbon blocks cut to conform to the slightly curved contour of the anvil the steel plate was fitted in place and fastened with suitable bolts. Cast-iron rod was then bonded to the anvil surface and to the inserted steel plate to a depth of approximately $^{3}/_{4}$ in. This was then covered with a coating of Haynes Stellite $^{1}/_{4}$ in. in thickness. The casting was finally turned in the fire and the plate was heavily reinforced on the under side of the anvil, with the new modified high strength bronze-welding rod.

The second photograph shows clearly the rotor used in this type of fuel hog. Close examination of the notches in which the knives are inserted will show deposits of Haynes Stellite as well as worn places prior to hard-surfacing. This rotor is of cast-steel construction and is mounted with 16 knives. After 3 years of service considerable wear had developed on both ends of the knife inserts. These worn places continually fill with splinters, causing a great deal of trouble in the adjustment of the knives and in their replacement. The worn sections of the rotor as well as the steel plates used as cutting edges were hard-faced and the process has proved to be very satisfactory and economical.

This broken and badly worn fuel hog which was about to be scrapped was completely built up and put back into service at a cost far below that for a new machine. Although this is but a single example of the efficiency which results when hard-facing materials and the oxyacetylene process for repair are applied to reduce abrasive wear, it serves to indicate the almost unlimited possibilities of this process.



Knife Notches in the Hog Rotor during Rebuilding by Hard-Facing

A Stronger Frame

By S. C. CLARK

✦Mr. Clark is connected with the Technical Publicity Department of The Linde Air Products Company.

BREAKAGE occurring in two 4-ton lift cranes used by a large manufacturing company in the East for unloading freight cars and trucks recently caused considerable consternation in the transportation and maintenance departments. These cranes are mounted on a four-wheel truck so that it is possible to load and unload merchandise and also carry it about the plant. It was found that the cranes, either from overloading or structural weakness, had given way in their main base castings. Four cracks in one crane had so weakened the frame that it had become bent or sprung at least 6 in. out of alignment.

Calculations indicated that new castings would cost, to start with, $395.00 each. In addition there would be at least forty rivets to cut out in each frame, all of the machinery would have to be dismantled which would cost at least $75.00 more, and another $100.00 would have to be allowed for reassembly of these units. All in all, about $600.00 each was considered as a fair estimate of the repair cost to these frames if they had to be replaced. As the plant already had a well developed oxyacetylene welding department, the welding superintendent was asked to estimate what a welded repair would cost. His estimate was so low compared to the estimate for complete replacement that the job was given to the welders.

As the crane trucks could be turned over on their sides, no dismantling of the fractured parts was necessary. After they had been turned over, a large heating blowpipe head was attached to the oxyacetylene welding blowpipe and the bent frame heated and pulled straight. Then the cracks were chipped out to give a good vee for welding.

The next day the welding work started. It was found that the first frame was still slightly out of line, so it was reheated and put in alignment just prior to the welding operation. As the operator felt that the bending or straightening of the casting might have caused a condition of stress at the top, he welded this part first, following which he completed the welding on the underside. This welding procedure tended to relieve any bending stresses that might have been left in the steel casting. When the weld had been completed a reinforced pad 3 in. wide and about 1 in. thick was built up in order to give this section of the casting extra strength.

The repair time on this casting was about 11 hr., during which time about 18 lb. of high test steel welding rod was used. Immediately following this successful repair to the first truck, the second truck was started and finished with results equally as successful.

Aside from the hundreds of dollars saved, another ad-

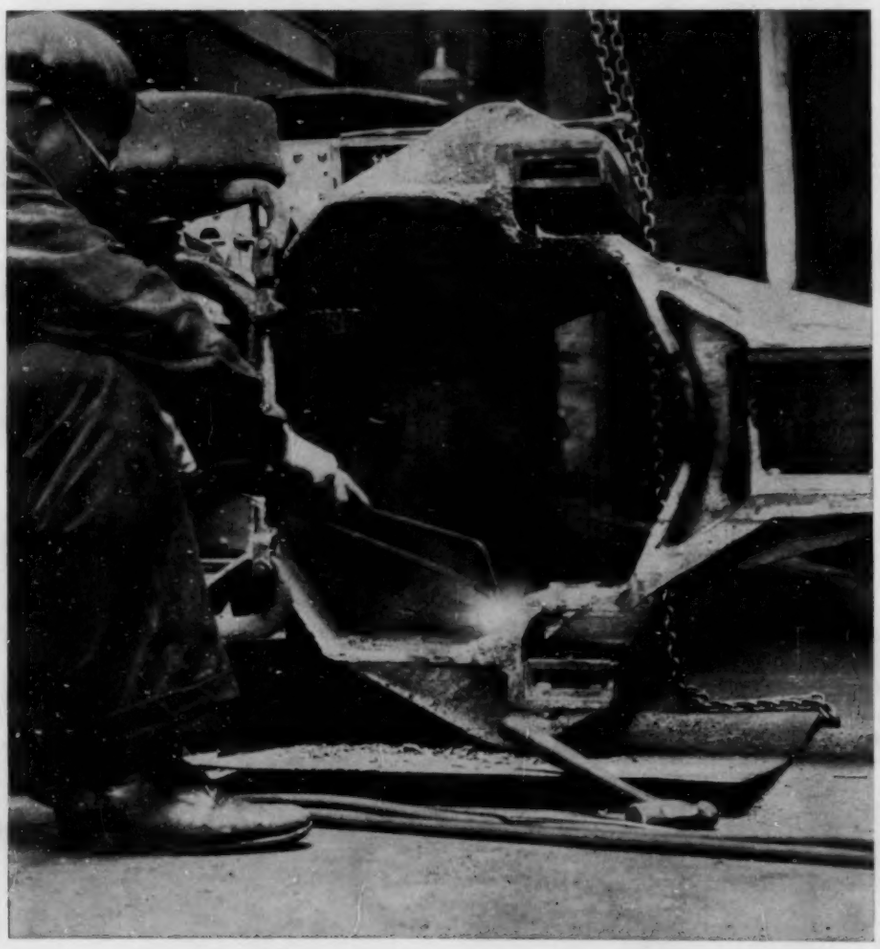
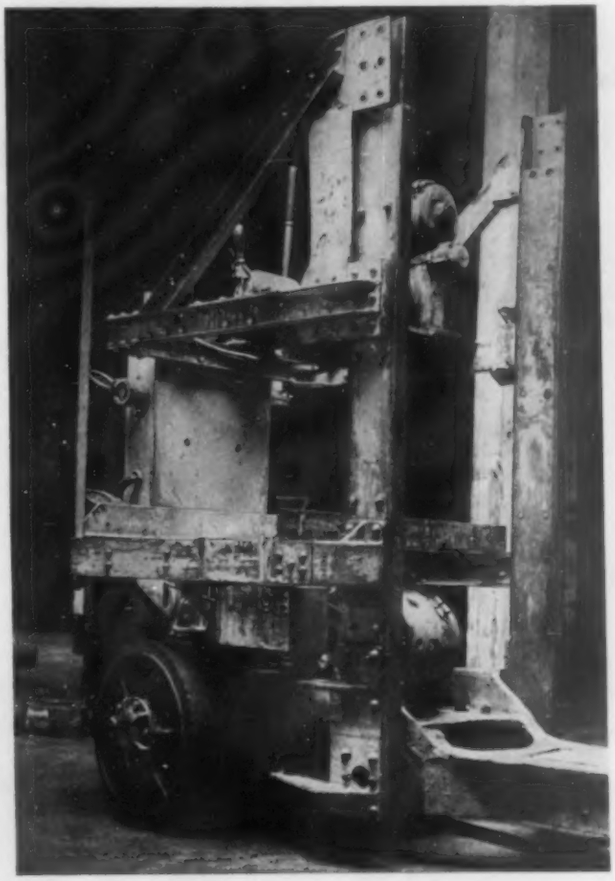


Fig. 1—With the Truck on Its Side, the Cast Steel Frame Is Repaired and Strengthened

vantage of this welded repair lies in the fact that even though new castings had been secured, there would still have been an equal chance of their breaking in the same place as the old castings, whereas with the welded repair the points subject to stress were actually made stronger than the new part.



The Main Horizontal Frame in the Truck Crane Shown on the Right Is Now Stronger than New

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Fall Meeting

The Meetings and Papers Committee invites suggestions of all the members of the Society for papers to be presented at the Fall Meeting of the Society to be held in Detroit during the week of October 2nd in connection with the Metal Congress. These suggestions should be received not later than June 1st.

Engineers' Week

Chicago Century of Progress

The Chicago Section will participate in Engineers' Week which is the week beginning June 25th during which time 20 Societies will hold meetings. On Thursday morning, June 29th, starting at 10 A.M., there will be a half-day session devoted to welding papers which will be followed by a luncheon and round table discussion. Following the luncheon those attending the meeting will be taken in groups over the Fair grounds and shown those welded features of particular interest.

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"I'll call you up!"

A HUSBAND bids his wife goodbye as he leaves in the morning. "I'll call you up," he says reassuringly.

A guest leaves after a pleasant week-end. "I'll call you up," she tells her hostess. An executive sits at his desk handling varied business matters, large and small. "I'll call you up," he answers many times in the course of a busy day.

"I'll call you up" is a phrase that has become part of our language and part of our modern security.

Beneath the surface meaning of the words is something more than a casual promise to maintain contact. It is a phrase of confidence and a phrase of friendship. Implied in it is a nearness to everything and everybody.

The familiar gesture of lifting the telephone receiver holds boundless possibilities. It may avert a danger, end an anxiety, solve a dilemma, insure an order. Or it may be for some trivial pleasant purpose—a jest to be shared, a greeting to be spoken.

Over the telephone speed the thoughts and ideas that change destiny, bring new hope to the wondering and greater achievement to the ambitious. Over the telephone come the "Yes" and "No," the "I'll be there" and the "Come at once" that signify decision and create action.

Think what this world would be like if you could not telephone so easily to so many people. No friend or place is ever far away when you can say—"I'll call you up."

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